

PATTERNS OF HABITAT SELECTION AND DENSITIES OF
WHITE-TAILED DEER ON AND AROUND QUIVIRA NATIONAL
WILDLIFE REFUGE

Final report

Submitted by:

JONATHAN CONARD

Sterling College, Sterling, KS 67579

Kansas State University Principal Investigator:

DAVE HAUKOS

U.S. Fish and Wildlife Service Point of Contact:
RACHEL LAUBHAN

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TABLE OF CONTENTS

Project Outline.....	
Project Objectives.....	
Chapter 1: Patterns of private land use by white-tailed deer in relation to cropland habitat types.....	
Chapter 2: Habitat use by white-tailed deer in relation to prescribed fire.....	
Chapter 3: Spatial and temporal variation in deer densities and group size at Quivira National Wildlife Refuge.....	
Literature Cited.....	

Project Outline

This project was conducted to provide additional analysis of GPS and VHF data that was initially collected from white-tailed deer at Quivira National Wildlife Refuge (QNWR) between 2007 – 2009. The primary objectives of the additional analysis were to: 1) assess patterns of habitat selection by male deer in response to specific crop types and prescribed fires, and 2) to assess temporal variation in patterns of private land-use by both male and female white-tailed deer, particularly in relation to the hunting season. In addition, continued distance-sampling surveys were conducted during both 2010 and 2011 and results of these surveys were analyzed and compared to previous data collected on QNWR from 2007-2009.

The current project successfully completed these objectives and the following report should provide useful information relevant to management of the white-tailed deer population at QNWR. In addition, with the documented occurrence of CWD in Stafford County from a deer harvested during the 2011 hunting season, the combined data from this report and Blecha et al. (2010) should provide important information about conditions prior to CWD arrival and can also be used to inform management decisions designed to mitigate CWD spread on and around the refuge.

We thank Kevin Blecha, Lloyd Fox, Rachel Laubhan, and Lee Jones for providing assistance and support with various aspects of the project. We thank Leonore Enfield, Tyler Wise, and Ian Sparks for assisting with distance sampling efforts.

Project Objectives

1. FURTHER ANALYSES OF EXISTING VHF and GPS DATA (separate analysis of VHF and GPS collar data);

Two main purposes are to: (i) evaluate how deer use landscape relative to habitat availability (esp. GPS buck data) at different times/events; and (ii) explore if any of the buck and doe “fixes” found near captive game farms near refuge.

A. Analysis of existing female VHF data to determine:

- a. Female movement responses in relation to off-refuge hunting seasons (archery/muzzleloader & rifle)
- b. The monthly proportion of telemetry locations on private land

B. Analysis of male deer GPS data to determine specific movement patterns and habitat use in relation to the following factors:

- a. Movements in relation to the hunting season including patterns of private land use, movement distances, and home range size before, during, and following hunting season (archery and firearms).
- b. Daily timing of private land use patterns by male deer.
- c. Seasonal patterns of resource selection for specific crop types on private land and on food plots on Quivira.
- d. Short-term movement responses in relation to burn events and habitat selection in relation to burn patterns over the past two years.
- e. Habitat use in relation to tree removal and mowing (if data is sufficient for analysis)

2. ADDITIONAL DATA COLLECTED USING SPOT-LIGHT SURVEYS

(implementing a long-term monitoring program for distance sampling)

- A. Conduct distance sampling surveys on 6 sampling occasions between 1 October - 15 March. Data from distance sampling transects will be used to determine a point estimate of density for the QNWR deer population, estimates of group size, and estimates of group densities as part of a long-term monitoring of trends in deer population or group density that may occur on QNWR.

Chapter 1: Patterns of private land use by white-tailed deer in relation to cropland habitat types

Introduction

Deer may consume agricultural crops when available with consumption being lowest when natural vegetation is actively growing and higher during other times of the year (Smith et al. 2007). Cropland areas may also be locations where deer congregate for feeding, particularly on wheat fields (*Triticum aestivum*) during the fall and early winter. White-tailed deer are often perceived as causing a high level of damage to agricultural crops when compared to other wildlife species (Conover and Decker 1991).

Cropland areas are used primarily for feeding by deer and may be areas where multiple social groups of deer form loose aggregations. In open foraging sites, larger group sizes may be associated with an increased efficiency of foraging due to reduced vigilance needed to detect predators when foraging as part of a group (Lark and Slade 2008). Thus, higher rates of association between male deer in cropland areas may be an adaptation for increasing foraging efficiency and reducing predation risk (Bowyer et al. 2001).

Since the area and types of croplands within public lands may be manipulated as part of management strategies, it is necessary to investigate factors underlying the observed relationship between croplands and contact. We hypothesize that habitat use may not be consistent across all cropland areas, but that characteristics of cropland areas (field size, type of crop, distance to cover) may influence contact rates.

Patterns of private land use by white-tailed deer may depend on the availability and phenological stages of various cropland areas but may also exhibit seasonal or even daily

variation. Understanding the timing and frequency of which deer use private lands can provide insight into the magnitude of impact that management actions and hunting regulations on private lands would be expected have on the deer population at QNWR and the potential for movement of disease on / off of the refuge. With a captive ungulate facility near the refuge it is also important to determine if deer are coming into close proximity to captive ungulate facilities, which could possibly result in direct contact between wild and farmed cervids (VerCauteren et al. 2007).

Methods

Cropland analysis- We delineated the boundaries of fields surrounding Quivira National Wildlife Refuge (QNWR) using 2006 and 2008 aerial imagery and assigned crop types based on data from the USDA Farm Services Agency (FSA). All agricultural fields (except for some fallow, CRP, and hayed fields) were readily distinguishable from the aerial imagery. In cases where the edge of the field was not apparent, we utilized 2003 and 2005 aerial imagery, as these fields would generally appear as a different crop type, and thus edges were easily identified. Croplands were subdivided by specific crop types for the 2008 and 2009 growing seasons. However, we regarded a particular crop type to be representative of that cropland patch for the duration of the entire year, as specific dates for crop residue removal, graze-out, as well as planting and harvesting dates were unknown.

Ground verification on some fields was also done in the summers of 2008 and 2009 from public roads adjacent to tracts of private land for verification purposes. We grouped FSA crop/forage records into eight crop types: alfalfa, corn, fallow, other, small grains (including winter wheat and rye), sorghum (milo), soybeans, and unknown. Of these crops, sorghum was planted in only a few fields that overlapped with home ranges of deer and therefore was not used

for analysis. Because crops are often rotated annually, and field boundaries may change from year to year, we digitized fields for both the 2008 and 2009 growing seasons.

We tested for habitat selection by deer in relation to crops by using a design III analysis in which both use and availability of cropland areas were measured for each individual deer (Manly et al. 2002). We defined availability for each deer by generating a 100% minimum convex polygon using all locations for that deer that were recorded during the study period. Within this polygon we calculated the percentage of various crop types for a given year to measure availability. If the home range of a deer did not include any crop fields during that year that individual was not used for further analysis. To calculate actual use of crop fields by deer, we measured the total number of locations of deer that were recorded in various crop types. We measured use and availability for small grains (winter wheat or rye), corn, soybeans, alfalfa, and fallow fields. We analyzed data separately for 2008 and 2009 for each of the following time periods: January – April, May – August, September – December. We chose these time periods since they generally corresponded to crop phenology and planting / harvest dates. For January – April time periods we analyzed only small grains, alfalfa, and fallow crop types since corn and soybeans would not have been growing during this time period. We did not analyze data from September – December 2009 because we did not have data for winter wheat that would have been planted during this time period. For September-December 2008, we used available data collected from summer 2009 to determine small grains crop types that were planted during September – December 2008.

We used the package “ADEHABITAT” in Program R to calculate resource selection ratios (w) and test for habitat selection in burned and unburned areas (Calenge 2006). If resource selection ratios were > 1.0 this indicated that deer used that type of habitat more frequently than

expected by chance. If ratios were < 1.0 this indicated that deer used that type of habitat less than expected by chance.

We determined the fixed kernel utilization distribution for all male deer from January – April 2009. We used the average utilization distribution value for winter wheat crop fields to measure the intensity of use for each field. For each field we also measured the area, distance to nearest woodland patch, and distance to Quivira National Wildlife Refuge. We used multiple regression to determine if the utilization distribution value was related to the size of crop field, distance to nearest woodland patch, or distance to Quivira National Wildlife Refuge. We also compared the utilization distribution value between winter wheat crop fields used by deer that were on and off of Quivira National Wildlife Refuge.

We measured the distance to the nearest field edge and distance to nearest woodland patch for locations of deer that occurred on small grain fields between January 2008 – April 2008 and October 2008 - April 2009. We used a Mann-Whitney Rank Sum test to compare distances of these locations to distances of an equal number of random points generated within each crop field.

Private land use analysis- The proportion of locations on private land were calculated for each male deer during the following 4-hr time periods: sunrise (0500 - 0859), morning (0900 - 1259), afternoon (1300-1659), sunset (1700 – 2059), early night (2100 – 0059), late night (0100 - 0459). Differences in the use of private land during these time periods was tested using Friedman's Repeated Measures Analysis of Variance on Ranks test (SigmaStat).

We compared average distance moved by male deer between private land and on the refuge. To assess movement patterns we distinguished between transitions by deer from one area of Quivira to another area of Quivira (QNWR – QNWR), from Quivira to private land or

from private land to Quivira (QNWR – PRIVATE), and from private land to another location on private land (PRIVATE-PRIVATE). GPS locations were recorded at 3.5 hour intervals from September - May and we censored locations that were taken over 4 hours after the previous location for the analysis. We used a Kruskal-Wallis test to compare average distances moved for these three types of movements (QNWR – QNWR, QNWR-PRIVATE, PRIVATE-PRIVATE) and conducted pairwise comparisons using Dunn's test (SigmaStat).

Rifle season for the deer management unit (Unit 5) around Quivira National Wildlife Refuge was from 3 – 14 December 2008. In 2009, rifle season was from 2 – 13 December. In both 2008 and 2009, archery season ran through December 31st. We used a one-way ANOVA to test for differences in the proportion of locations on private land for time periods before rifle season (19 – 30 November 2008, 19-30 November 2009), during rifle season, post-rifle season (17 – 28 December 2008, 17-28 December 2009), and post-archery and post-rifle season (1-12 January 2009). A Kruskal-Wallis test was used for situations in which our data failed to meet assumptions of normality necessary for parametric testing procedures.

Results

Cropland habitat selection - The majority of the fields surrounding Quivira National Wildlife Refuge were planted to winter wheat during the study period. Other crops that were planted included corn, soybeans, sorghum, and alfalfa.

Deer selectively used cropland habitats during January – April 2008 ($\chi^2 = 97.4$, $df = 26$, $P < 0.001$), January-April 2009 ($\chi^2 = 593$, $df = 22$, $P < 0.001$), May-August 2008 ($\chi^2 = 354.3$, $df = 17$, $P < 0.001$), May – August 2009 ($\chi^2 = 613.9$, $df = 18$, $P < 0.001$). During January – April 2008, deer used winter wheat fields more than expected while male deer neither preferred or

avoided other types of crops (Table 1). During January – April 2009, deer used alfalfa fields less than expected but confidence intervals on selection ratios for all other specific crop types overlapped 1.0 (Table 1). In May-August 2008 deer used corn fields more than expected, while in May-August 2009 and deer used alfalfa fields more than expected and soybean fields less than expected (Table 1). During September – December 2008, deer used winter wheat fields less than expected and corn fields more than expected based on availability (Table 1).

The frequency that deer were located on crop fields varied seasonally during 2008 and 2009 for some crops. When comparing the use of various types of crops by deer, the highest proportion of deer locations were found on small grains (winter wheat / rye) during March and April of 2008 (Figure 1) and 2009 (Figure 2). Deer also used fallow fields more frequently from July - August of 2008 and 2009 than during the rest of the year (Figure 1). Corn was used by deer most frequently during July of 2008 (Figure 1) and 2009 (Figure 2). Soybeans and alfalfa were used relatively infrequently during all months in 2008 and 2009.

The distance to the edge of a crop field was not significantly different between deer points ($N = 1403$) located within small grain fields between October 2008 and April 2009 and equal number of random points generated within the boundaries of the same fields (Mann-Whitney Rank Sum test, $P = 0.107$). For January 2008 – April 2008, there was no significant difference between the distance to the nearest field edge when comparing deer locations ($\bar{x} = 45.6$ m) and random locations ($\bar{x} = 50.9$ m) (Mann-Whitney Rank Sum test, $P = 0.24$).

On average, deer locations on small grain fields during October 2008 – April 2009 were slightly closer to woodland patches ($\bar{x} = 867.1$ m) than random points ($\bar{x} = 917.7$ m) but this difference was also not statistically significant (Mann-Whitney Rank Sum test, $P = 0.093$). For

locations of deer on small grain fields during January 2008 – April 2008, there was also no significant difference between the distance to the nearest woodland patch when comparing deer locations (\bar{x} = 463.1 m) and random locations (\bar{x} = 522.6 m) (Mann-Whitney Rank Sum test, P = 0.11).

Seasonal and daily patterns of private land use- Use of private land by male deer differed according to time of day (χ^2 = 53.04, df = 5, P < 0.001) and was highest during time periods encompassing 1700 – 0400 hrs. Significant differences in the proportion of locations on private land were present when comparing both late night and early night time periods to morning and afternoon time periods (P < 0.05). The morning time period also differed significantly from the sunset and sunrise time periods (P < 0.05). The average proportion of locations on private land were lowest during the morning (0.286) and highest during the late night time period (0.430) (Fig. 3.)

Movement distances differed according to whether deer were transitioning between QNWR and private land or whether they were moving within QNWR or within private land. The average distance moved was much greater when deer transitioned between QNWR and private land (\bar{x} = 866.6 m) than for distances moved between consecutive locations on QNWR (\bar{x} = 323 m) (q = 41.1, P < 0.05) or on private land (\bar{x} = 358.5 m) (q = 36.44, P < 0.05) (Fig. 4).

For the 2008 hunting season, there were no differences in the proportion of private land use that occurred between pre-rifle, rifle season, post-rifle, and post-archery / post-rifle time periods for all deer (H = 2.44, P = 0.49), male deer only (F = 0.12, P = 0.95), and female deer only (H = 1.65, P = 0.65) (Fig. 5). For the 2009 hunting season, there were also no differences in the proportion of private land use that occurred between pre-rifle, rifle season, post-rifle, and post-archery / post-rifle time periods for all deer (H = 2.7, P = 0.26), male deer only (F = 0.08, P

= 0.92), and female deer only ($H = 1.18$, $P = 0.56$) (Fig. 5). The use of private land tended to peak during winter (January – February) and was lowest during the summer months (May – August). Male deer tended to use private land more than female deer during all months (Fig. 6). It was not uncommon for male deer to be located relatively long distances (>1.6 km) away from the refuge ($N = 719$). Locations of male deer on private land were recorded up to 3998 m from the refuge with an average distance from the refuge of 730.4 m.

Four male deer had at least one location recorded within 50m of a captive ungulate facility that is located on private land adjacent to the refuge. There were a total of 191 locations of male deer recorded within 50m of the facility and the surrounding private land area was regularly used by male deer during the study period (Figure 7).

Discussion

The composition of the landscape may influence habitat use, movements, and migratory patterns of deer (VerCauteren and Hyngstrom 1994). In our study, small grains (winter wheat / rye) are the most common crop within the predominantly agricultural landscape surrounding Quivira National Wildlife Refuge. This type of crop was used most frequently by deer, and was preferred by deer in winter time periods during some years of our study. The quality of forage that is available for white-tailed deer during the winter may influence survival and reproductive success (DePerno et al. 2000). While deer will utilize a variety of forage species during the winter; it is known that cereal grains, including winter wheat, contain sufficient protein and phosphorous levels to meet nutritional requirements of deer during the winter months (Wiggers et al. 1984). Since winter wheat meets nutritional requirements of deer it may be preferred over native forage species and result in deer use of winter wheat fields when native vegetation is not actively growing (Nixon et al. 1991). We observed that deer were located on winter wheat fields

most frequently during March and April, which may be a result of increasing levels of protein and phosphorous present in winter wheat during the late winter (Wiggers et al. 1984) and a lack of actively growing native vegetation available for consumption. A reduction in deer use of winter wheat may occur during late developmental stages (May – June) as maturation of beards on wheat may result in reduced deer browsing (Springer 2010).

In addition to winter wheat, deer used a variety of other crop types including corn, alfalfa, and fallow fields. Use of corn by white-tailed deer peaked during the summer which is consistent with observations that deer will consume corn during the summer (Nixon et al. 1991) and that home ranges may shift closer to corn fields during the tasseling-silking developmental stage (VerCauteren and Hyngstrom 1998). We observed little use of corn fields in the months immediately following harvest, which differs from other studies in which deer utilized waste grain in corn fields (Nixon et al. 1970) and used standing corn during the winter (Grovenburg et al. 2010). While deer are known to consume soybeans during the growing season (Nixon et al. 1991), we observed little use of soybean fields by deer during the study period.

Fallow fields were used by deer most frequently during the summer (May-August) and were not avoided by deer during any season. The use of fallow fields by deer during the summer months was unexpected and to our knowledge has not been documented in other agricultural systems. It is known that forbs constitute a substantial portion of the diet of white-tailed deer during the growing season (Daigle et al. 2004, Smith et al. 2007) and that fallow fields may host a variety of broad-leaf weed species (Derksen et al. 2001). Depending on the timing and type of tillage that occurs in fallow fields, it is possible that the presence of forbs may be the reason that white-tailed deer utilized fallow fields during the summer. There was a high degree of variability in deer selection for fallow fields during the summer and part of this variation may

have been due to differences in tillage practices between various landowners and the subsequent impact on the forb community present in fallow fields.

The intensity of use of crops by deer has been shown to be related to the distance from the nearest woodland edge, with the greatest intensity of consumption of crops by deer occurring near the edge of the field (Rogerson 2005). However, we did not find any significant difference between the average distance to the field edge or nearest woodland patch when comparing actual locations of deer and random locations. It is possible that proximity to edge habitats may be a mechanism to avoid predation and that in refuge areas (i.e. QNWR) that deer may be more apt to use crop areas away from woodland edges. It is also possible that many of the areas bordering crop fields may consist of grasslands or other fields, which would provide little additional cover and limited incentives for deer to use edge areas adjacent to these other types of habitat.

Private land use varied seasonally and according to the time of day. Deer typically had the greatest proportion of locations on private land between sunrise – sunset, with a lower proportion occurring on private land during daylight hours. This suggests that deer may be using private land during the night (probably to forage on available crops) and returning to QNWR during the day. Male deer appeared to move longer-distances when traveling between QNWR and private land than when consecutive locations were recorded within QNWR or private land. This could be due to deer moving directly to preferred foraging locations on private land that may be located some distance off of the refuge and spending time foraging in these locations before returning to QNWR. Seasonal patterns of private land use also varied, with private land being used most frequently by deer from November – April. This observed pattern may be related to wide-ranging movements by male deer in search of mating opportunities during the rut and also movement that may occur by both male and female deer onto private lands for foraging

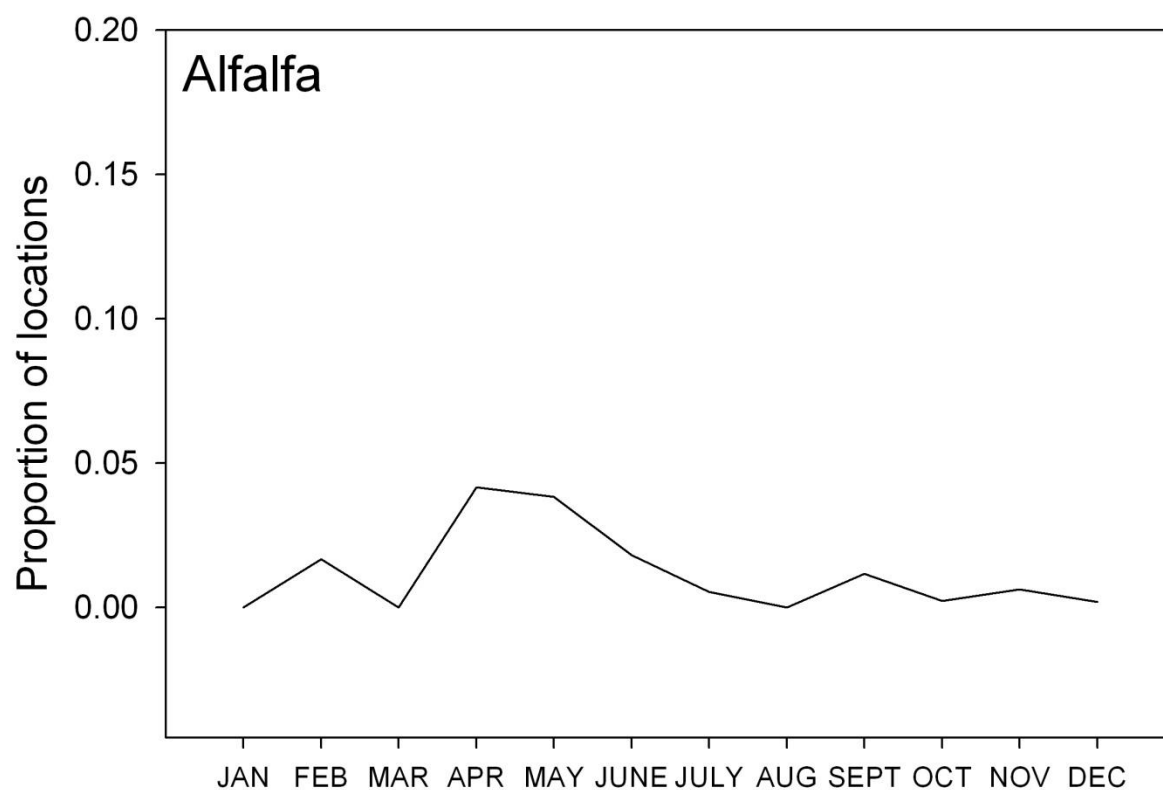
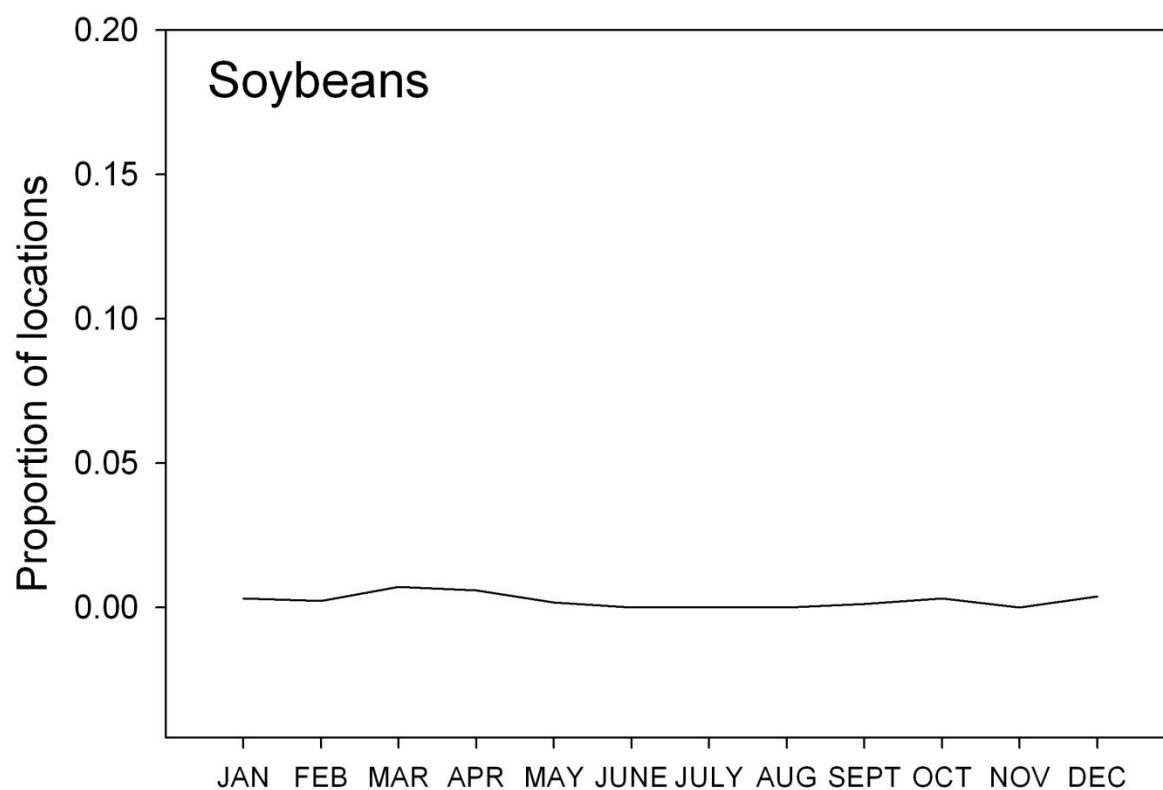
on winter wheat fields during late winter. Male and female deer did not exhibit significant differences in the proportion of locations on private land in relation to rifle season. While deer were using private at approximately the same intensity before, during, and after rifle season it is possible that deer may have altered their behavior in other ways such as avoiding roads or increasing nocturnal activity (Kilgo et al. 1998).

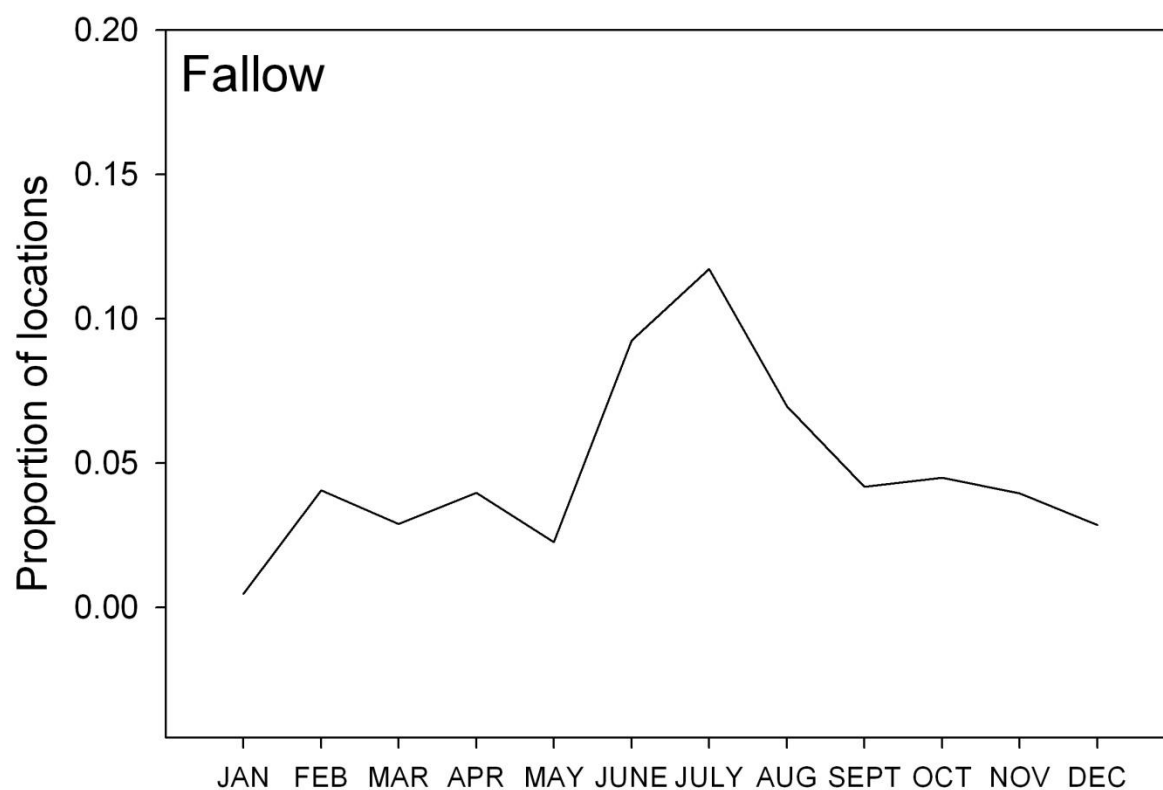
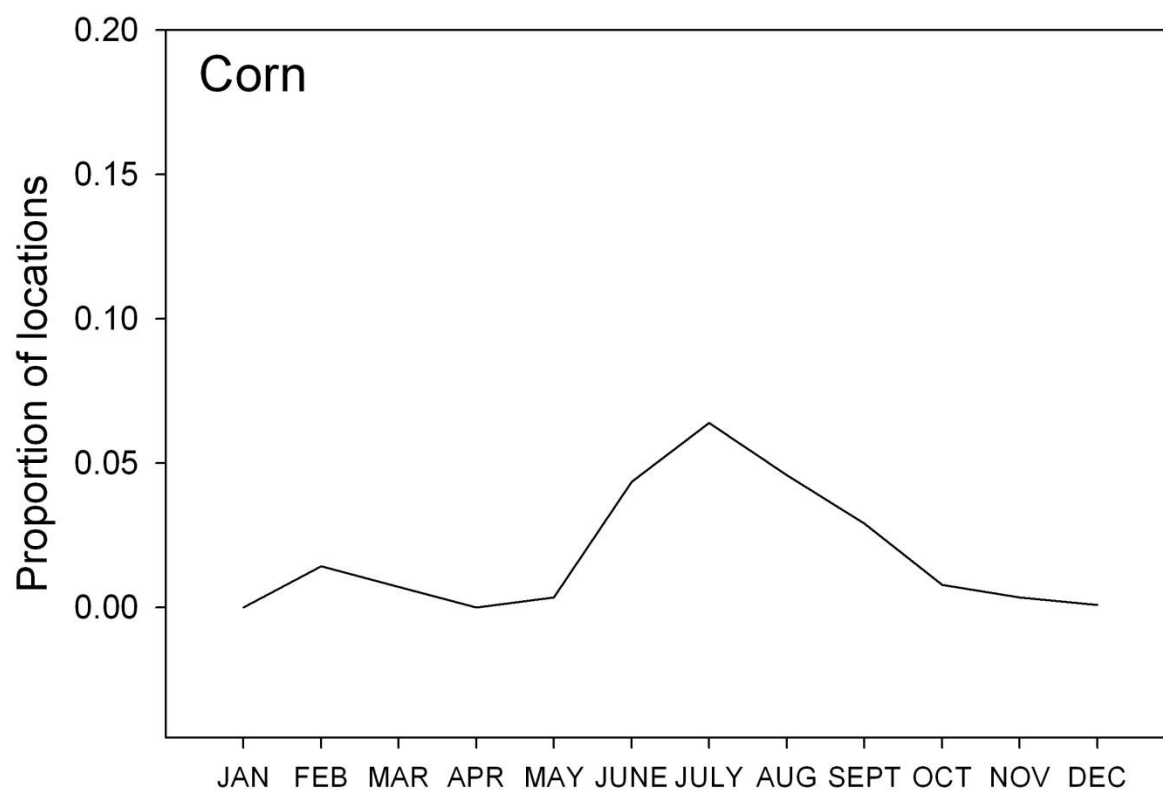
Management strategies

Since deer used habitat selectively with respect to agricultural crops, it may be possible to use existing crop fields on Quivira National Wildlife Refuge as a means of managing distributions and movement patterns of deer. Winter use of crop fields by deer focuses primarily on winter wheat and deer used crop fields both on and off of the refuge. Since deer typically congregate in larger groups during the winter and contact rates are higher during this season (Blecha et al. 2010), the presence of winter wheat food plots on Quivira National Wildlife Refuge would likely be sites of high contact between multiple social groups of deer and could also become a concentrated site for indirect transmission due to repeated use of the same fields by deer on a seasonal and annual basis. The patterns of long-distance movements (>1.6 km) by male deer off of QNWR increase the likelihood of disease spread from neighboring areas of Stafford County onto the refuge. While it may not be possible to influence these types of movements it is important to be aware that they are occurring and may increase the likelihood of CWD being transmitted to deer on QNWR.

Table 1. Selection ratios (w_i) and confidence intervals of white-tailed deer use of various types of agricultural crops planted on and around Quivira National Wildlife Refuge in 2008 and 2009.

Year	Season	Alfalfa		Small Grains		Fallow		All other habitats		Corn		Soybeans	
		w_i (SE)	95% CI	w_i (SE)	95% CI	w_i (SE)	95% CI	w_i (SE)	95% CI	w_i (SE)	95% CI	w_i (SE)	95% CI
2008	January – April	1.92 (1.25)	-1.37, 5.21	1.59 (0.19)	1.06, 2.11	0.83 (0.23)	0.23, 1.42	0.96 (0.02)	0.90, 1.02	--	--	--	--
	May – August	3.43 (1.35)	-0.12, 6.98	0.54	-0.13, 1.22	2.04 (0.67)	0.28, 3.81	0.93 (0.04)	0.82, 1.05	7.83 (1.62)	3.47, 12.19	0.24 (0.260)	- 0.44, 0.92
	September - October	1.42 (0.24)	0.79, 2.06	0.50 (0.18)	0.03, 0.98	1.18 (0.54)	-0.22, 2.58	1.03 (0.03)	0.95, 1.12	2.67 (0.62)	1.08, 4.27	--	--
2009	January - April	0.89 (0.02)	0.85, 0.94	0.94 (0.35)	0.86, 1.02	0.87 (0.27)	0.21, 1.53	0.94 (0.03)	0.86, 2.61	--	--	--	--
	May - August	5.59 (1.52)	1.58, 9.60	0.52 (0.21)	-0.02, 1.07	2.74 (1.47)	-1.13, 6.63	0.96 (0.05)	0.84, 1.08	3.67 (2.17)	-2.07, 9.41	0.24 (0.14)	- 0.13, 0.61





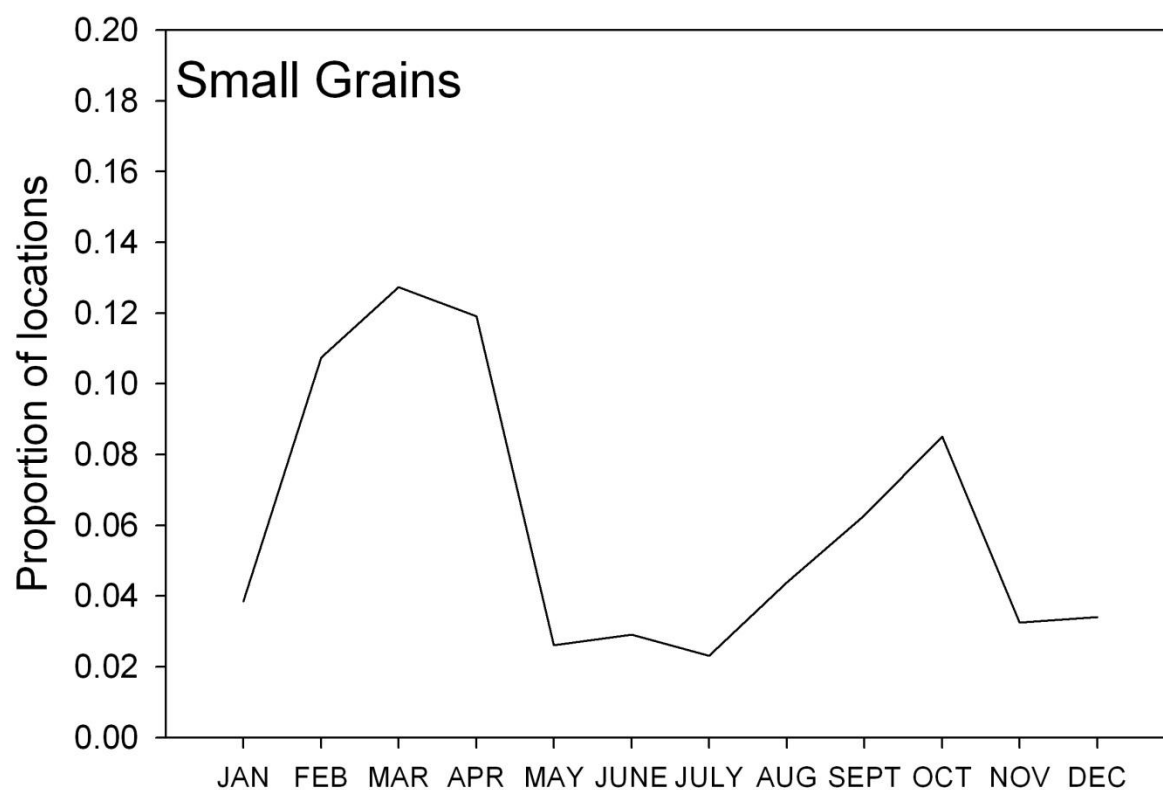
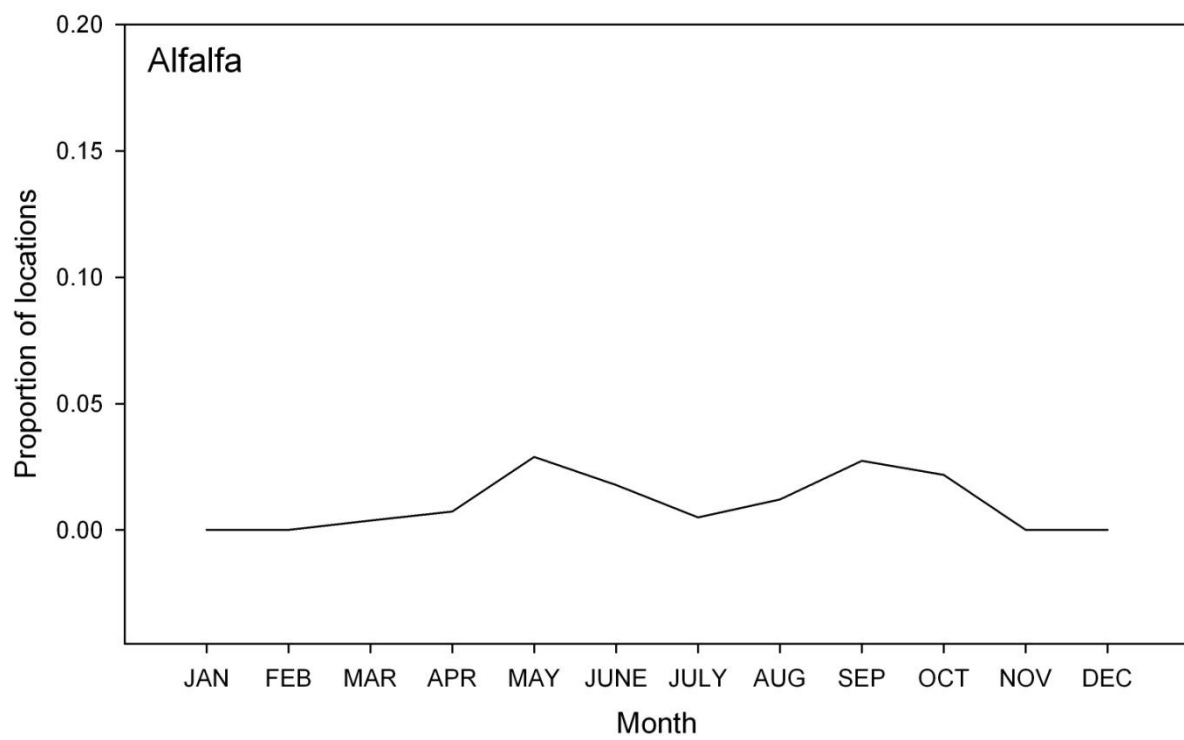
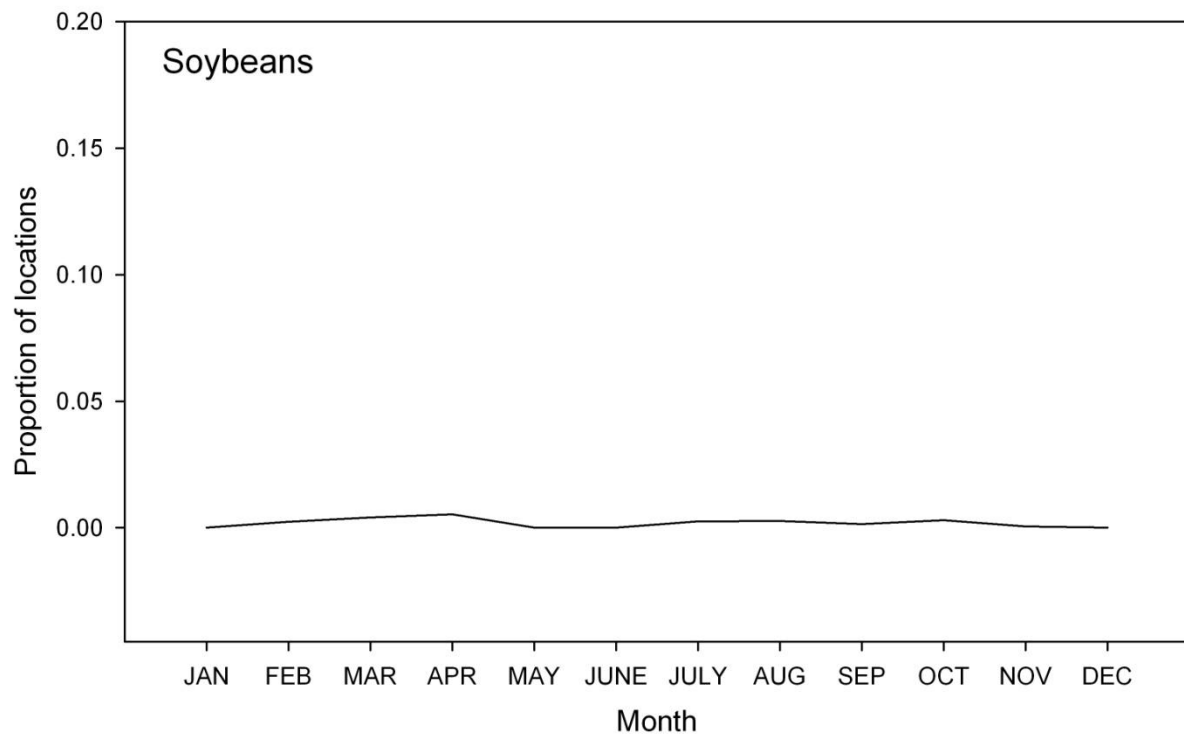
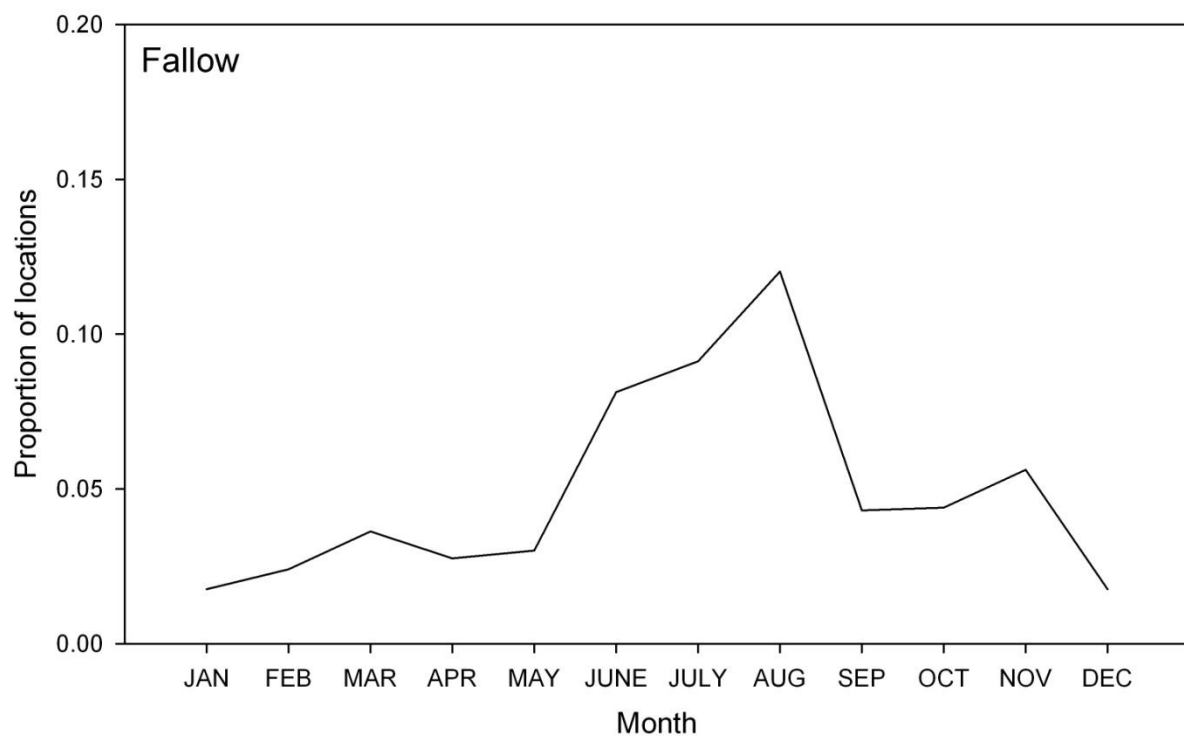
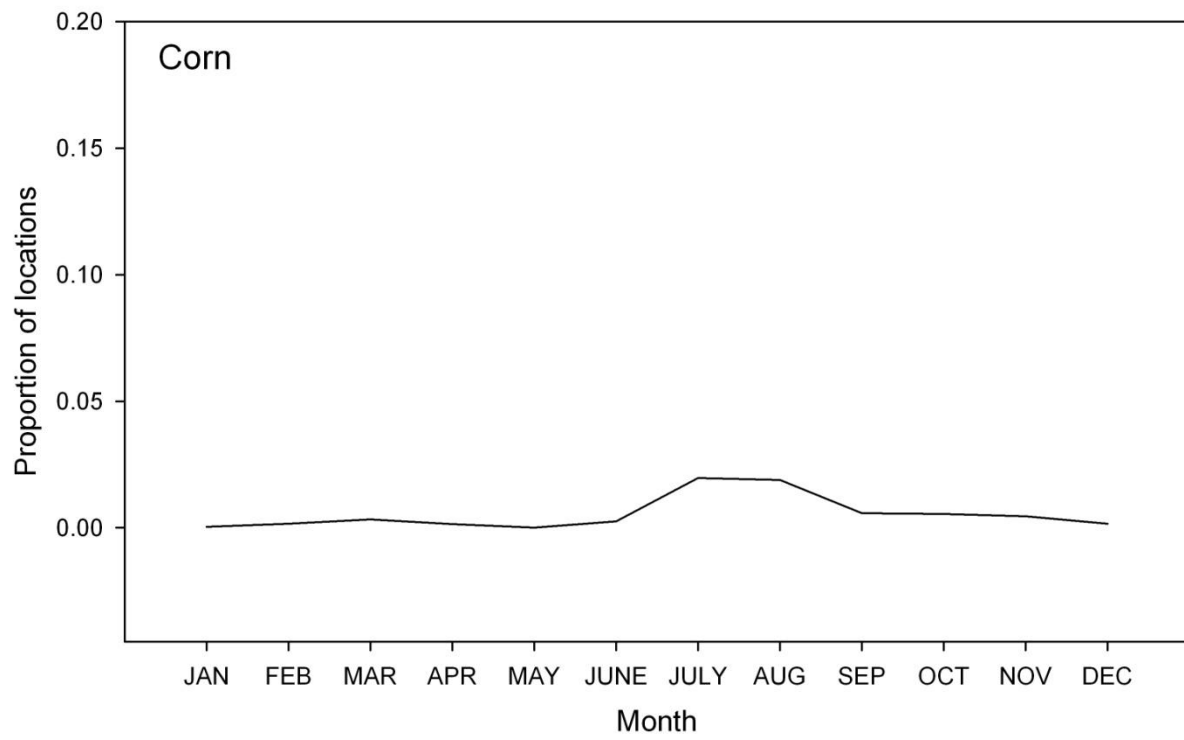


Figure 1. Proportion of male deer locations recorded on soybeans , alfalfa, corn, fallow, and small grains during 2008.





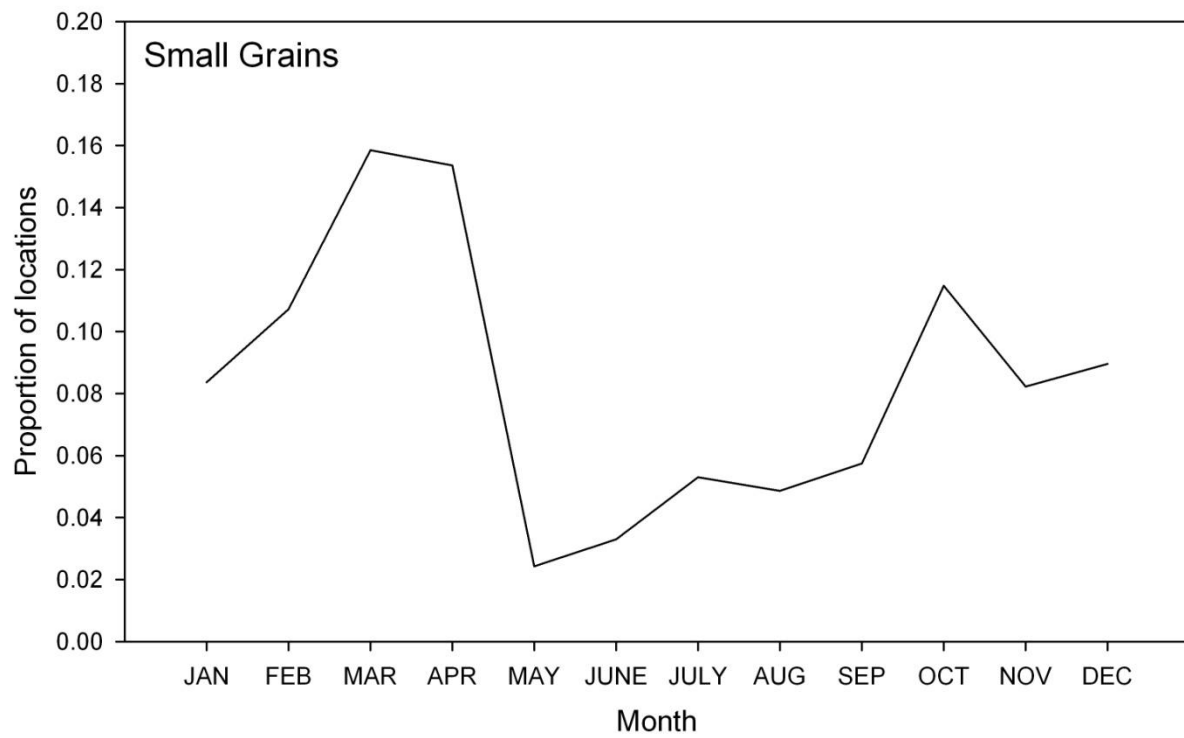


Figure 2. Proportion of male deer locations recorded on soybeans, alfalfa, corn, fallow, and small grains (e) during 2009.

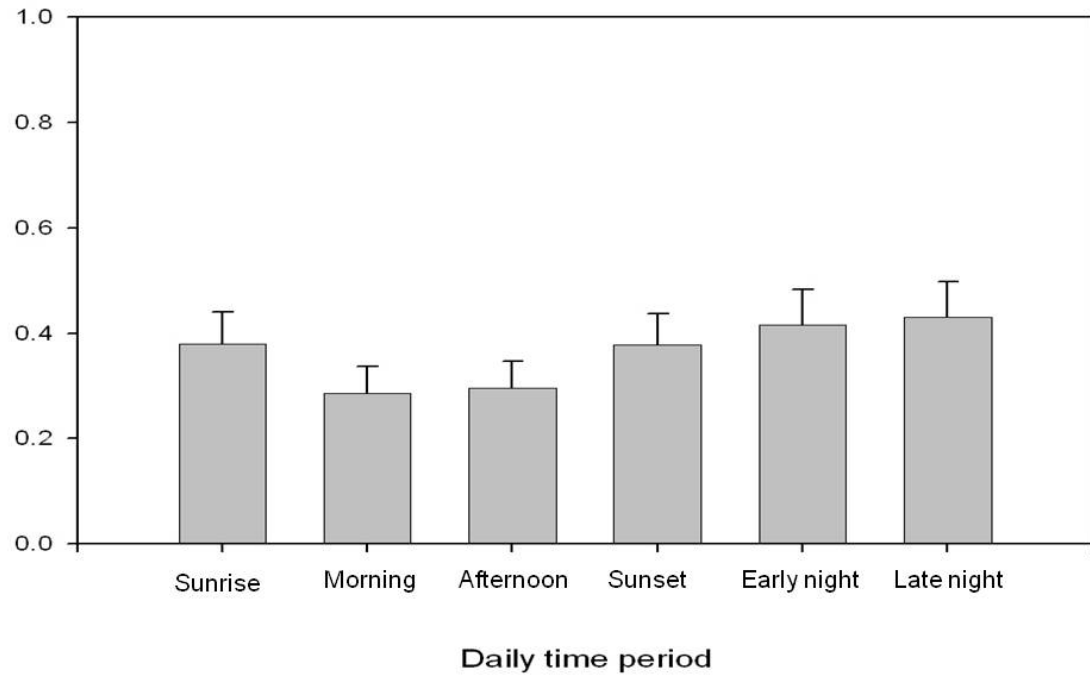


Figure 3. Average proportion of locations of male deer on private land (\pm SE) during different times of day.

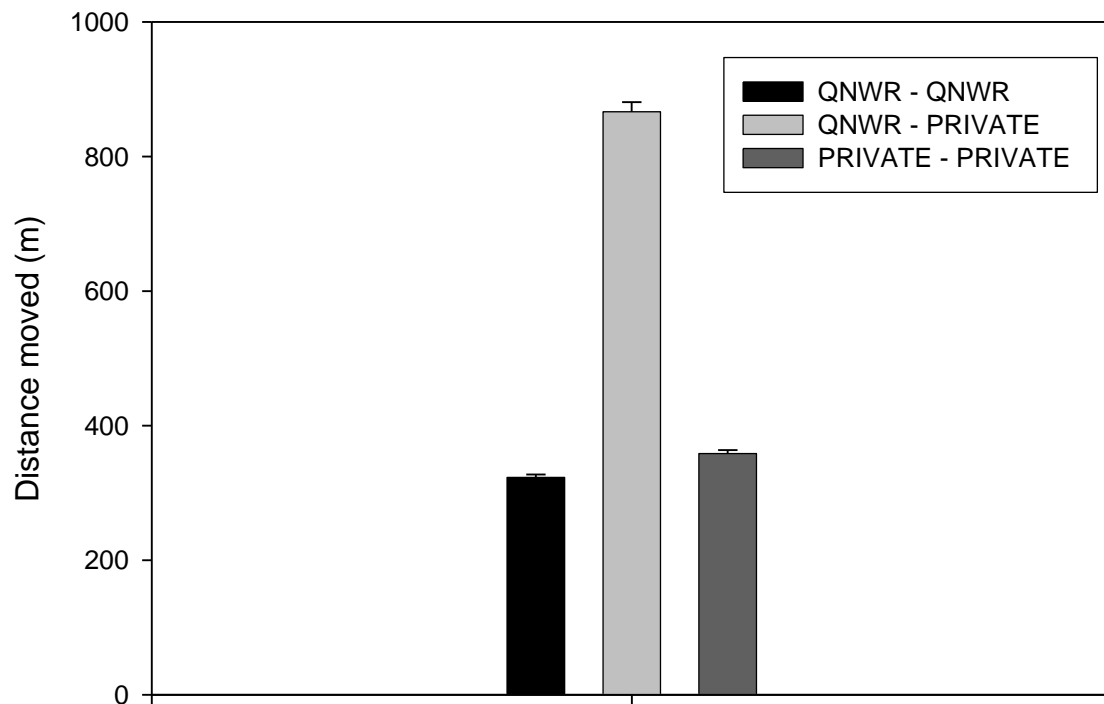
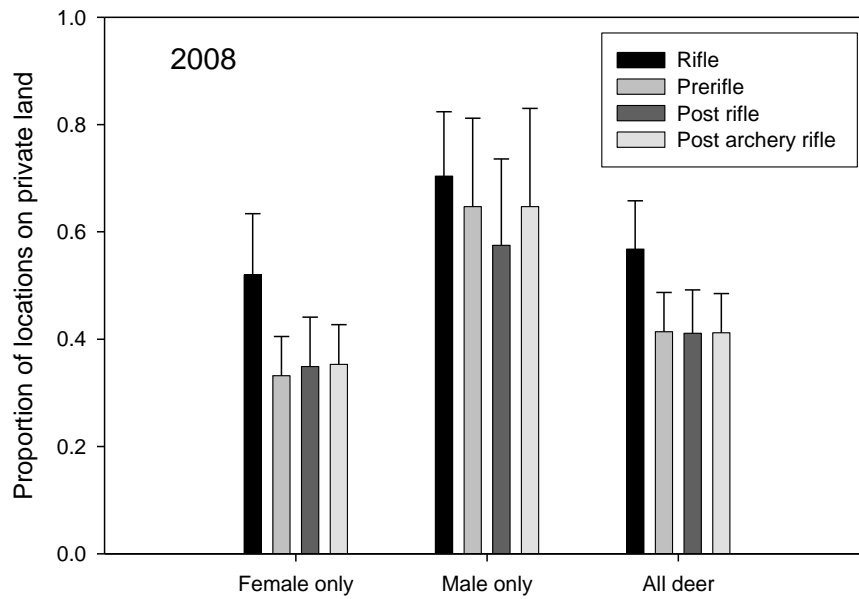


Figure 4. Average distances moved by male white-tailed deer (\pm SE) for various types of transitions on and between Quivira National Wildlife Refuge and private land.

(a)



(b)

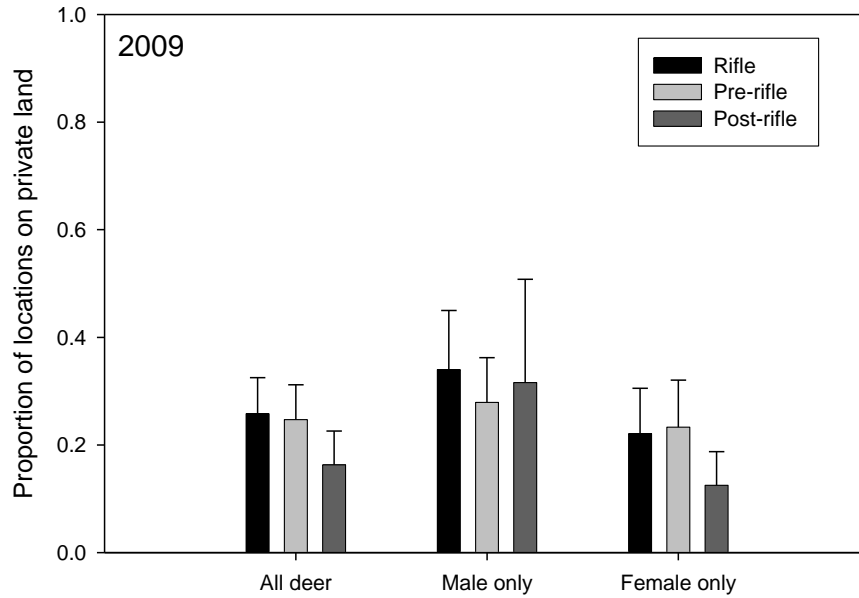
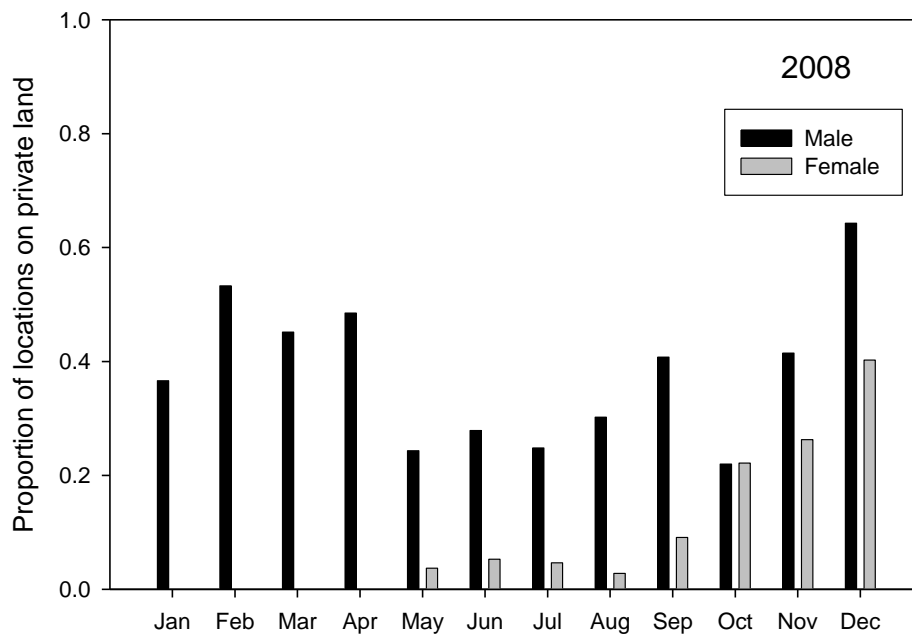


Figure 5. Mean proportion of locations on private land (\pm SE) for white-tailed deer preceding, during, and following the 2008 (a) and 2009 (b) rifle season.

(a)



(b)

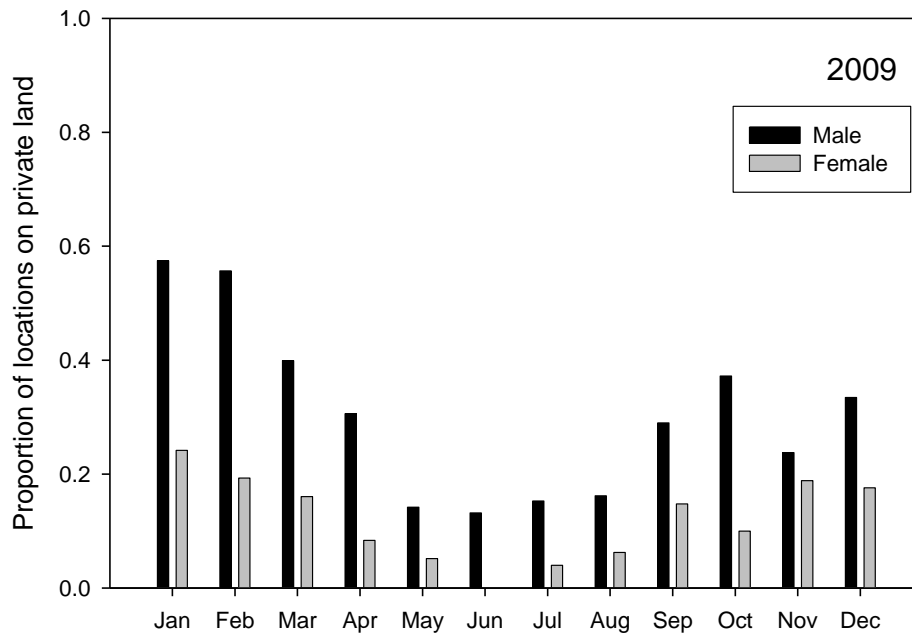


Figure 6. Monthly proportion of locations on private land by male and female deer in 2008 (a) and 2009 (b) at Quivira National Wildlife Refuge.

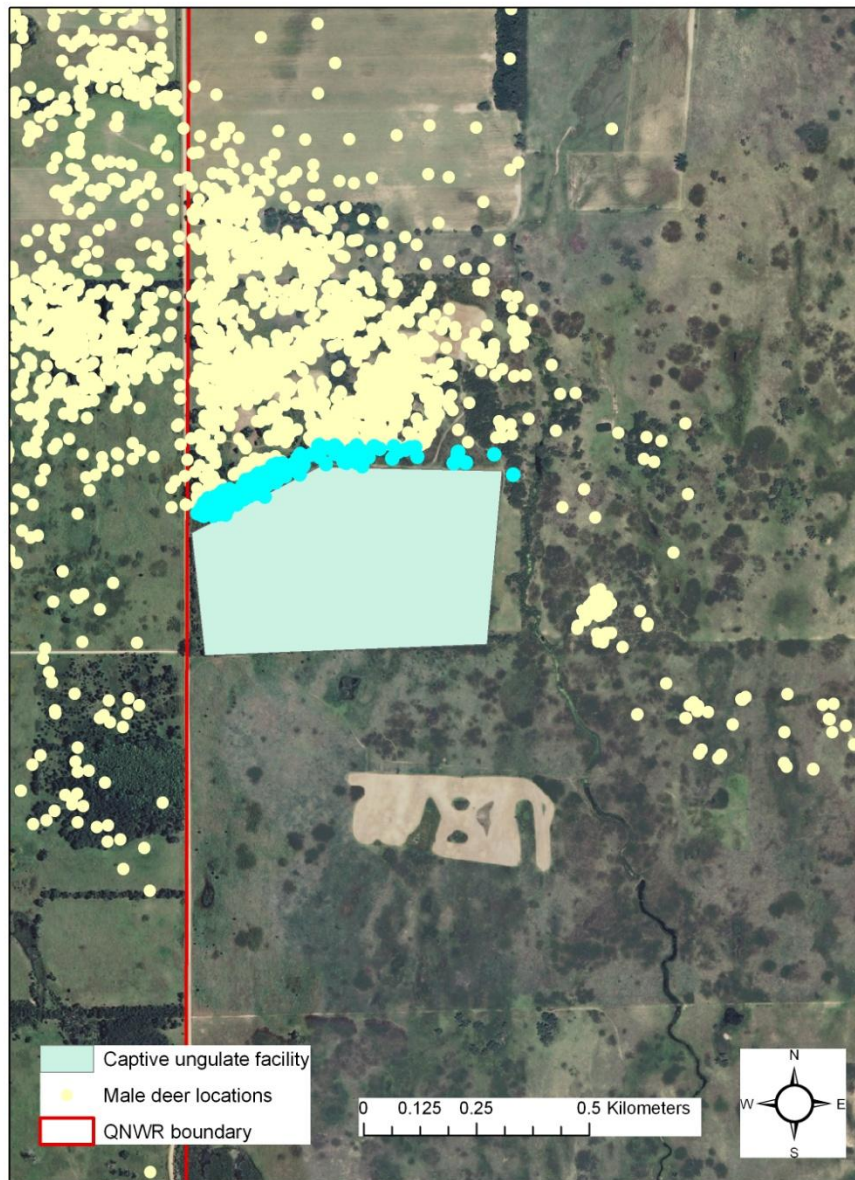


Figure 7. Locations of male deer adjacent to captive ungulate facility near boundary of Quivira National Wildlife Refuge. Blue dots represent locations of male deer within 50m of the boundary of the facility.

Chapter 2: Habitat use by male white-tailed deer in relation to prescribed fire

Introduction

Natural disturbances including fire and grazing play an essential role in maintaining the structure and function of grassland systems. Historically, prairies in the central United States were grazed by large herds of bison (*Bos bison*) and experienced periodic fires that occurred approximately every 3-5 years as a result of lightning strikes or intentional burning by Native Americans (Wright and Bailey 1982, Kimmerer and Lake 2001). The presence of periodic fires serves as an essential component of maintaining prairie systems and can influence nutrient cycling, plant species diversity, and plant biomass. Burning in grassland systems increases aboveground biomass in the growing season following fire (Tracy and McNaughton 1997, Knapp et al. 1998). Fire also promotes the dominance of native C₄ grasses while reducing the abundance of C₃ forbs unless accompanied by grazing by large herbivores such as bison (Collins et al. 1998). On a landscape-scale, fire is critical to maintaining grassland systems and regular burning acts to directly suppress encroachment by woody vegetation (Briggs et al. 2002).

Fire in prairie systems has been demonstrated to impact a wide range of species including small mammals, grasshopper, birds, and bison (Kaufman et al. 1998). In tallgrass prairie systems, burning of grassland vegetation promotes the dominance of graminoid species and increases the total amount of aboveground biomass available for ungulate grazers (Abrams et al. 1986). Prescribed burning may enhance forage quality for native grazers by improving both protein (Van Dyke and Darragh 2007) and nutrient content (Tracy and McNaughton 1997). In tallgrass prairie, bison preferentially graze on areas that have been burned the previous spring (Vinton et al 1993, Knapp et al. 1999) and elk (*Cervus elaphus*) also prefer burned areas in rough

fescue grasslands (Jourdonnais and Bedunah 1990), sagebrush communities (Van Dyke and Darragh 2006), and grassland-sagebrush communities (Pearson et al. 1995). However, since burning promotes the dominance of C₄ grasses in prairie systems, burned areas may not provide preferable foraging locations for species such as white-tailed deer that primarily consume browse and forbs instead of grasses (Anderson et al. 2001).

Short-term effects related to burning may include movement by deer towards streams or wetland areas as an immediate response to fire (Ivey and Causey 1984, Singer et al. 1989). Following the completion of a burn, burned areas may not be immediately used by deer due to the removal of forage (Ivey and Causey 1984). However, the overall home ranges of deer may not be dramatically altered in response to fire and they may quickly return to burned areas following the re-growth of vegetation (Ivey and Causey 1984). Mortality of deer in relation to fire has not been commonly reported, but it is known that severe fires may result in mortality of various cervid species and that if the timing of the burn does not allow for adequate regrowth of vegetation that the risk for winter mortality may be increased (Singer et al. 1989).

While the effects of prescribed fire on deer have been studied in other systems (i.e. Ivey and Causey 1984, Singer et al. 1989, Leslie et al. 1996) little is known about responses of white-tailed deer to prescribed burning in grassland systems. Since fire is frequently used as a management tool in grassland areas it is important to better understand the influence of prescribed burning on movements and distribution of white-tailed deer. We hypothesize that since fire may influence cover, biomass, and composition of grassland vegetation that prescribed burning may to have an influence on patterns of habitat selection by white-tailed deer (*Odocoileus virginianus*).

If fire influences movement patterns of deer it may also have an influence on disease dynamics including chronic-wasting disease (CWD) that can be spread by either direct or indirect contact between individuals. If fire results in short-term movements that increase contact between social groups this could promote the spread of disease. Similarly, if fire concentrates multiple social groups of deer on a common feeding site this may also increase the rates of direct and indirect contact and have potential implications for disease spread.

Our objectives were to 1) determine short-term responses of male deer to prescribed burns that occurred during the spring and late summer, 2) document longer-term patterns of habitat selection by male deer in relation to prescribed burns, and 3) to determine if prescribed burning resulted in changes in home range size.

Methods

We monitored the locations of male deer ($N = 24$) from November 2007 to January 2010. Male deer were outfitted with GPS collars (Advanced Telemetry Systems, Inc.) that were programmed to record locations every 3.5 hours from 1 October to 30 April and every 10.5 hours from 1 May – 30 September.

We recorded the locations of prescribed burns and wildfires that occurred on and around Quivira National Wildlife Refuge during 2007, 2008, and 2009. Only three areas on QNWR were burned multiple times during the study period. These areas made up a small portion of the study area and the size ranged from 1-33 acres. Spring burning at Quivira National Wildlife Refuge took place during March and April and we measured habitat selection of deer following spring burns (May, June, July, and August) to assess short-term impacts of fire on habitat selection by deer. We also measured habitat selection of deer during the 4-month period

(September, October, November, December) following late summer burning that occurred during July-August 2009 to test for short-term effects of summer burning on habitat selection by deer. Summer burning did not take place during 2007 or 2008. To test for longer-term effects of burning on habitat selection by male deer we examined deer habitat selection between January – April and May – September following burns that occurred during the previous spring.

We tested for habitat selection by deer in relation to burned areas by using a design III resource selection analysis in which both use and availability of burned areas were measured for each individual deer (Manly et al. 2002). We defined availability by generating a 100% minimum convex polygon using all locations of an individual deer that were recorded during the study period. Within this polygon we calculated the percentage of burned areas and unburned areas for a given year to measure availability. If the home range of a deer did not include any of the areas that were burned during that year that individual was not used for further analysis. To calculate use of burned and unburned areas by deer, we measured the total number of locations of deer that were recorded in burned and unburned areas.

We used the package “ADEHABITAT” in Program R to calculate resource selection ratios (w) and test for habitat selection in burned and unburned areas (Calenge 2006). If resource selection ratios were > 1.0 this indicated that deer used that type of habitat more frequently than expected by chance. If ratios were < 1.0 this indicated that deer used that type of habitat less than expected by chance. To assess whether habitat selection patterns varied between individuals we conducted an eigenanalysis of selection ratios (Calenge and Dufour 2006). If all individual deer selected habitat types in the same way than the first axis generated during eigenanalysis would explain the majority of observed variation in selection patterns. If patterns

of habitat selection differed between individual deer, than multiple axes would be required to explain the majority of variation in selection patterns (Calenge and Dufour 2006).

To determine if burning influenced the size of the home range for male deer we compared differences in size of the home range for deer during time periods before and after burning had occurred. We determined minimum convex polygon home ranges for all male deer using locations collected for the 2-month period prior to burning (February – March 2009) and determined if these home ranges included areas that were burned during March-April 2009. We also determined home range sizes for male deer during the 2-month time period post burning (June-July 2009) and calculated the difference in home range size between the February-March and June-July home ranges. We compared the differences in size of home ranges between these time periods for deer that had burning take place within the home range and deer that did not. We did not have a sufficient sample size to compare home range differences in 2008.

Results

The majority of deer had home ranges that included areas that were burned at least once during the study period. However, the home ranges of three male deer did not include any areas that were burned between 2007-2009. Burned areas typically comprised a small portion of the overall home ranges of deer for burns that occurred during spring 2007 (\bar{x} = 6.7%), spring 2008 (\bar{x} = 4.1%), spring 2009 (\bar{x} = 9.6%), and summer 2009 (\bar{x} = 4.8%).

Short-term effects of burning -- Male deer selectively used habitat with respect to burned areas from May – August following spring burning in 2008 ($\chi^2 = 32.7$, $df = 2$, $P < 0.001$) and 2009 ($\chi^2 = 177.2$, $df = 6$, $P < 0.001$). In both years, deer used burned areas less frequently than expected during the 3-month time period following spring burning (Table 1). During the 3-month time period following summer burns that occurred during 2009, deer also selectively used

available habitat with respect to burns ($\chi^2 = 286.3$, $df = 6$, $P < 0.001$). Following summer burns, deer used burned areas less than expected and used unburned areas more than expected (Table 1). Deer were infrequently located within burned areas during the months immediately following burning during spring 2008 (Fig. 1), spring 2009 (Fig. 2.) or summer 2009 (Fig. 3).

Eigenanalysis of selection ratios indicated that patterns of habitat selection by male deer were similar across all individuals following spring burning in 2008 and 2009 and following summer burning in 2009.

In one instance, a male deer was located in a burned area on the day following burning. However, it typically took much longer for male deer to use burned areas after they had been burnt. For instance, male deer were not observed to use areas that were burned in the spring of 2008 for an average of 56 days following the burn (range = 30-82 days, $SD = 33.9$). In 2009, it was an average of 39 days (range = 1-76 days, $SD = 35.1$) following burning before male deer used areas after prescribed burning.

Long-term effects of burning-- Burning during the previous spring did not impact habitat selection by male deer in the following January – April or May - August time period based on burns that occurred during 2007 (Table 2). However, habitat was selectively used by male deer during September – December 2008 ($\chi^2 = 75.7$, $df = 5$, $P < 0.001$), January-April 2009 ($\chi^2 = 482.6$, $df = 5$, $P < 0.001$), and May-August 2009 ($\chi^2 = 173.3$, $df = 2$, $P < 0.001$) following spring burning in 2008. During this time period male deer used burned areas less than expected during each time period (Table 2). Following spring burns in 2009, deer used habitat selectively during the following September-December time period ($\chi^2 = 150.71$, $df = 5$, $P < 0.001$). Deer appeared to use burned areas somewhat less frequently than expected although confidence intervals overlapped 1.0 (Table 2).

Home ranges—Burning did not impact average differences in home range size of male deer between time periods prior to spring burning (February-March) and following spring burning (June-July). Male deer whose home ranges were burnt had similar differences in home range size between these time periods when compared to male deer whose home ranges were not burnt ($t = -0.52$, $df = 11$, $P = 0.62$). Similarly, the home range size of deer during June-July did not differ according to whether deer had experienced spring burning within their home range during April-May ($t = -1.27$, $df = 11$, $P = 0.23$).

Eigenanalysis of selection ratios indicated that patterns of habitat selection by male deer were similar during January-April 2008 following spring burns in 2007. Patterns of habitat selection also did not differ for male deer in time periods following spring burning in 2008 or 2009.

Discussion

White-tailed deer may respond favorably to burning in some systems and preferentially use areas that have been burned. For instance, white-tailed deer preferred to use burned areas in mixed/prairie woodlands (Leslie et al. 1996) and mule deer (*Odocoileus hemionus*) were attracted to burned areas in a mixed chaparral habitat in California (Roberts and Tiller 1985). Use of burned areas by white-tailed deer increased in the weeks immediately following fire in a mesquite savannah region of Texas (Meek 2007). However, our results suggest that male deer often completely avoided burned areas for several weeks following burning and used burned areas of mixed-grass prairie less than expected in the 4 month time period following prescribed burning during the spring and late summer. This pattern is consistent with reports of deer avoiding severely burned areas immediately after fire (Ivey and Causey 1984).

The observed short-term response of white-tailed deer to prescribed burning may be due to changes to forage in burned areas or changes in the availability of concealment cover in burned areas. The effects of fire on forage quality and quantity for white-tailed deer may vary between different types of systems. In a loblolly pine system in the southeastern United States, Wood (1988) documented little substantial gains in forage production for white-tailed deer following the application of a prescribed burning. However, burning and timber thinning increased preferred forage for white-tailed deer in pine-oak woodlands and were recommended as a management tool to enhance deer habitat (Masters et al. 1996). In grassland areas, forbs may be heavily utilized by white-tailed deer during the growing season (Smith et al. 2007) and forbs may have lower biomass in burned areas (Abrams et al. 1986). Since burning reduces the abundance of C₃ forbs, which comprise an important part of the diet of deer, it is plausible that deer avoided burned areas because of a reduction in preferred forage. It is also possible that burned areas did not provide adequate concealment cover to serve as bed sites. While it is not uncommon to observe white-tailed deer bedding in grasslands throughout the study area during both diurnal and nocturnal periods (J. Conard, *unpublished data*), spring or summer burning may have removed enough vegetation to make these areas undesirable for bedding due to a lack of hiding cover.

Deer did not strongly avoid burned areas between 4-16 months following spring burning and did not exhibit a consistent pattern of avoidance or preference for burned areas during the study period. This suggests that short-term effects may be primarily due to the removal of biomass associated with the burn and that deer may use burned and unburned areas similarly after regrowth of vegetation has occurred. However, it should be noted that the majority of our sites were only burned once during the study period and that deer may respond differently to

spring burning that occurred annually, which would be expected to promote the dominance of C₄ grasses at the expense of C₃ forbs (Towne and Owensby 1984). We examined only late spring and summer burns, but it is also important to note that the season during which burning occurs may influence how fire effects the plant community. Deer may have responded differently to winter or early spring burns which can promote the presence of forbs (Towne and Owensby 1984) that may serve as important forage for deer during early summer (McCullough 1985, Smith et al. 2007).

Since male deer avoided burned areas we expected that burning might result in an increase in home range size to meet forage or cover requirements. However, we observed no change in home range size as a result of burning and it appears that deer simply used other areas within the home range. Since the size of the burned units were relatively small and typically comprised only a small portion of the overall home range of male deer it is possible that deer were able to acquire adequate forage without having to expand the size of the home range.

There is limited evidence that fire has short-term impacts on white-tailed deer survival, reproductive success or body condition (Ivey and Causey 1984, Klinger et al. 1989, Lewis et al. 2012). Our results suggest that fire in mixed-grass prairie may strongly influence patterns of habitat selection up to 4 months following a prescribed burn that occurs during the spring or summer. Thus, fire could be used as a management tool to influence short-term localized distributions of white-tailed deer without having strong direct impacts on demographic characteristics of the deer population. For instance, potential management applications could include a reduction in wildlife-vehicle collisions if burning was conducted in management units adjacent to areas where deer-vehicle collisions frequently occur. It may also be beneficial in

manipulating deer habitat use and shifting patterns of distribution according to management objectives.

Since male deer avoid burned areas it is possible that this would reduce the risk of indirect and direct contact between deer within these areas. This reduction in indirect contact rates could reduce the likelihood of CWD transmission between deer although this effect may be short-lived. The presence of burns could also serve as a mechanism to separate social groups during the summer following a spring burn. However, summer contact rates between male deer are typically lower than at other times of the year (Blecha et al. 2010) and this may not have a large impact on overall rates of contact between groups.

Table 1. Selection ratios for white-tailed deer in relation to burned and unburned areas on Quivira National Wildlife Refuge during May - August of 2008 and 2009.

Burn Date	Deer Location		Selection Index (<i>w</i>)	SE	Lower CI	Upper CI
	Dates	Habitat				
Spring 2008	May – August 2008	Burned	0.084	0.039	-0.004	0.172
		Unburned	1.034	0.031	0.965	1.104
Spring 2009	May-August 2009	Burned	0.289	0.219	-0.202	0.781
		Unburned	1.071	0.023	1.019	1.123
Summer 2009	September – December 2009	Burned	0.098	0.056	-0.027	0.224
		Unburned	1.079	0.026	1.023	1.137

Table 2. Selection ratios for white-tailed deer in relation to burned and unburned areas on Quivira National Wildlife Refuge in time periods following spring burns in 2007, 2008, and 2009.

Burn Date	Deer location dates	Habitat	Selection Index (<i>w</i>)	SE	Lower CI	Upper CI
Spring 2007	January – April 2008	Burned	1.094	0.083	0.908	1.281
		Unburned	0.977	0.031	0.908	1.05
	May – August 2008	Burned	1.53	0.141	1.214	1.845
		Unburned	0.926	0.053	0.807	1.045
Spring 2008	September – December 2008	Burned	0.436	0.115	0.179	0.693
		Unburned	1.022	0.012	0.994	1.049
	January – April 2009	Burned	0.074	0.031	0.005	0.144
		Unburned	1.086	0.022	1.037	1.135
	May – August 2009	Burned	0.028	0.02	-0.018	0.074
		Unburned	1.078	0.026	1.021	1.136
Spring 2009	September – December 2009	Burned	0.582	0.195	0.144	1.02
		Unburned	1.043	0.021	0.997	1.09

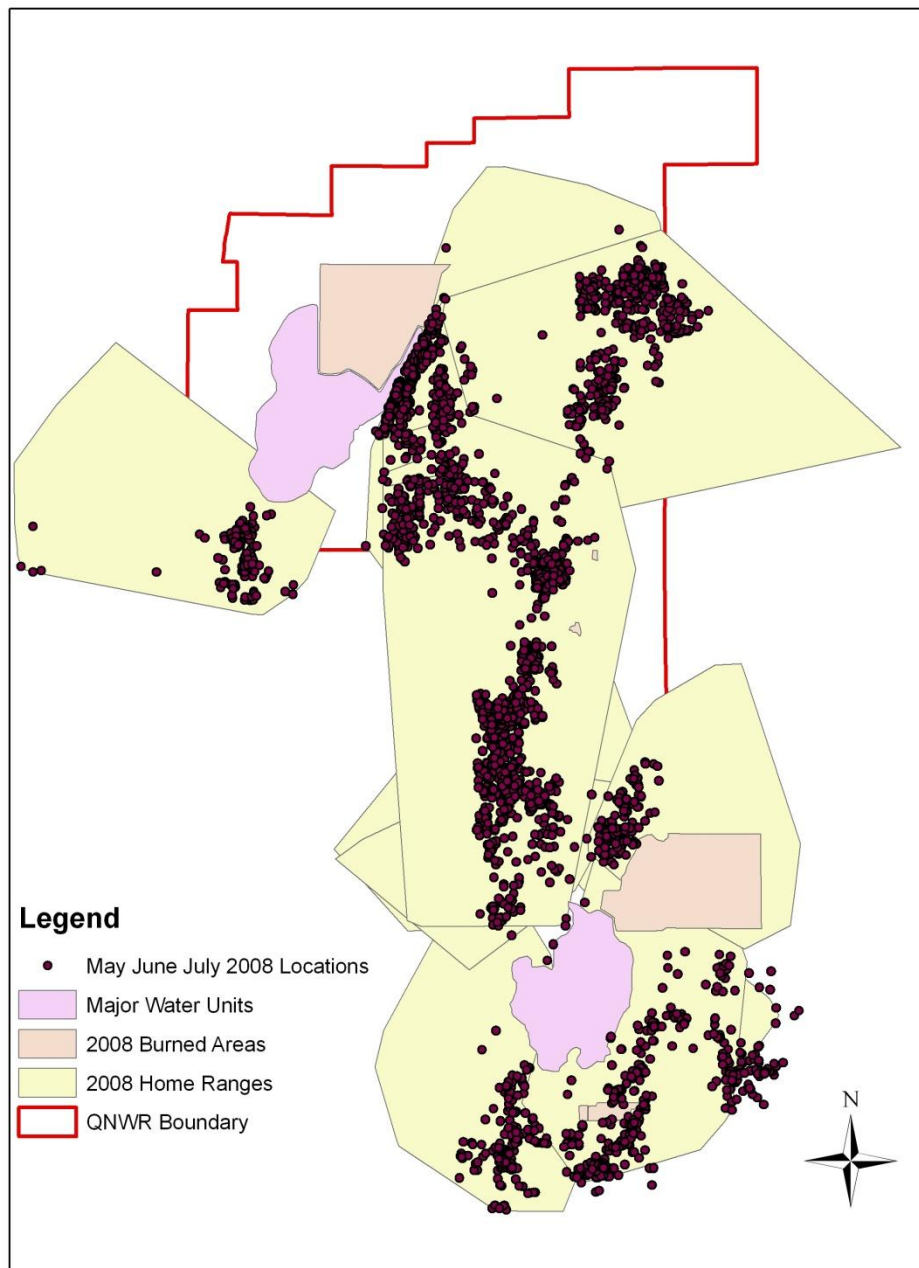


Figure 1. Locations of male white-tailed deer in May, June, and July 2008 in relation to areas burned in spring 2008 at Quivira National Wildlife Refuge.

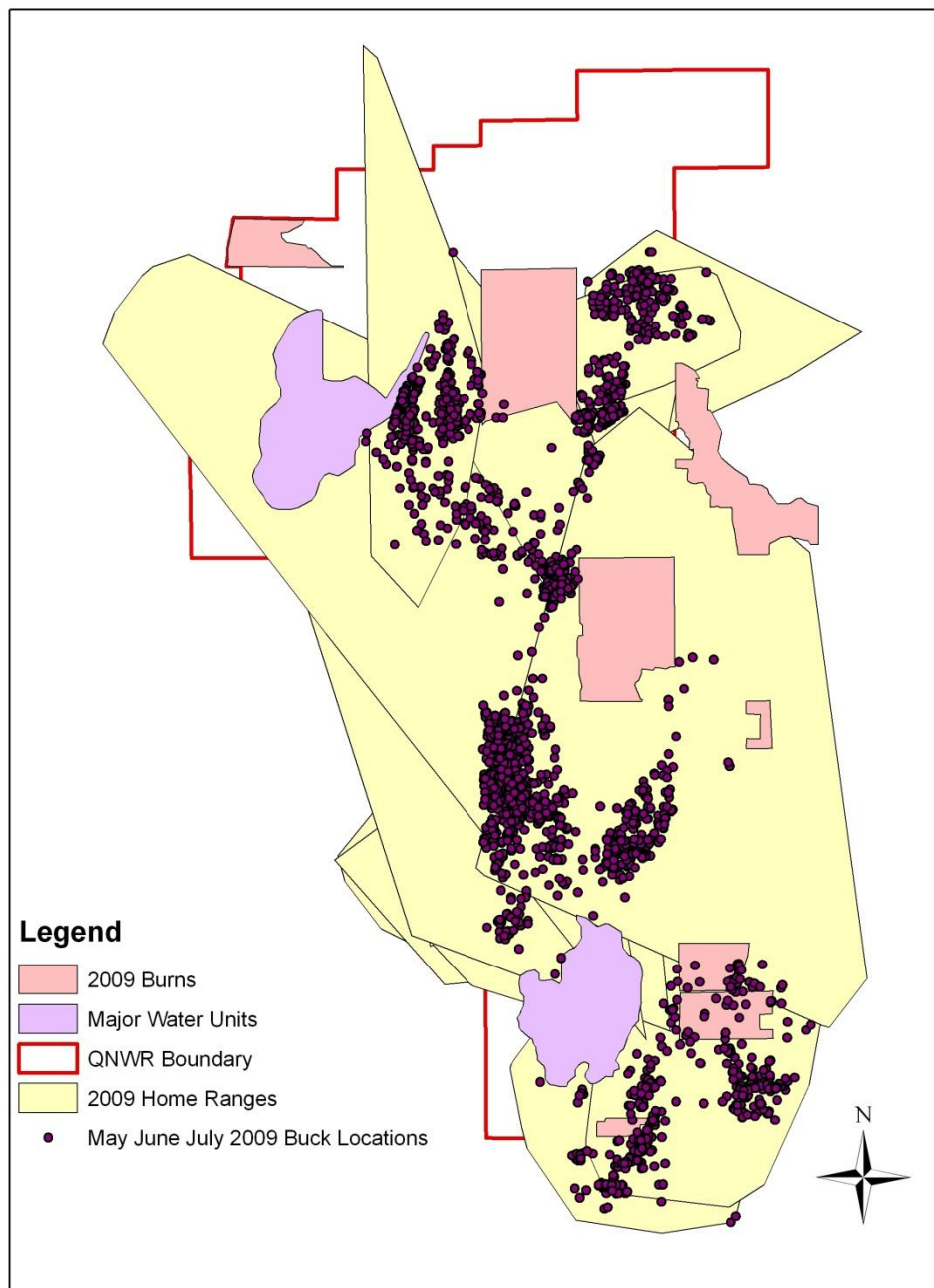


Figure 2. Locations of male white-tailed deer in May, June, and July 2009 in relation to areas burned in spring 2009 at Quivira National Wildlife Refuge.

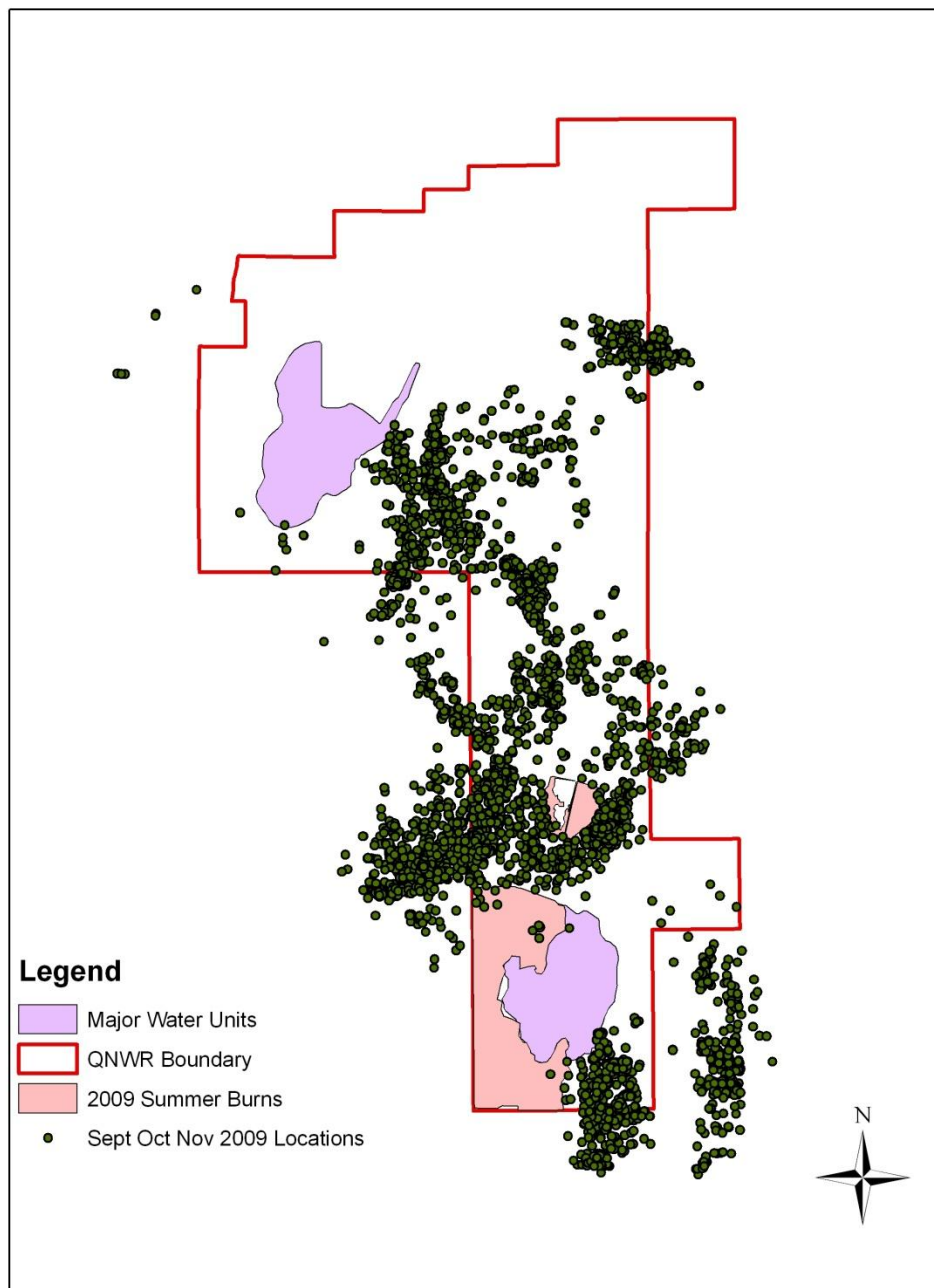


Figure 3. Locations of male white-tailed deer in September, October, and November 2009 in relation to areas burned during July and August 2009 at Quivira National Wildlife Refuge.

Chapter 3: Spatial and temporal variation in deer densities and group size at Quivira National Wildlife Refuge

Introduction

Recent evidence suggests that the expected impacts of chronic wasting disease on host populations may depend on rates of indirect transmission as determined by persistence of CWD in environmental reservoirs such as soil (Almberg et al. 2011). If high densities of deer result in higher concentrations of infectious shed prions within high-use areas it is possible that these areas may facilitate disease persistence and increase prevalence within a population (Almberg et al. 2011). Geographic or seasonal factors that result in high-density aggregations of multiple social groups may increase contact between matrilineal groups (Blanchong et al. 2006). For managers, geographic spread of CWD is important to minimize, as this disease can persist in the environment for an unknown amount of time (Miller et al. 2004, Johnson et al. 2006, Wiggins 2009).

Geographic heterogeneity in group density across QNWR may indicate that some areas are more prone to harboring multiple groups of deer. Considering that the home range of a deer group is not mutually exclusive, the probability is higher that a particular group of deer is coming into indirect contact with other social-groups than it would in a system with an even geographic distribution of social-groups. Seasonal heterogeneity in group density across QNWR may indicate that certain times of the year may be more conducive to indirect contact between groups.

Our objectives were to determine if deer on the QNWR study area exhibited annual, seasonal, or spatial variation in individual deer density (the total number of individual deer per unit area), group density (the number of deer groups per unit area) and group size (number of

individuals per deer group). We also sought to determine if landscape features, such as croplands or woodlands, were correlated with measures of deer or group density.

Methods

We conducted distance sampling surveys at Quivira National Wildlife Refuge during 2010-2011 (30 October 2010 – 5 March 2010, $N = 4$) and 2011-2012 (11 November 2011 - 21 April 2012). During 2010-2011, surveys were conducted using fourteen established line transects that ranged in length from 0.8 – 2.0 km. During 2011-2012, drier weather conditions allowed an additional transect to be included in the survey routes. These transects were part of 16 transects that have been surveyed annually since 2007. A single survey session consisted of driving all transect routes within a single night.

During the surveys, two observers scanned for deer using 1.5 million candlepower spotlights. Each observer was restricted to scanning for deer on their respective side (left or right) of the vehicle. GPS coordinates of the vehicles position were recorded upon the observer's detection of a group of deer. Next, distances (m) and azimuths ($1-360^\circ$) from observers to the focal group of deer (or solitary deer) were measured with a laser range finder and sighting compass. Group size, group composition (number of male / female deer), habitat type, and date/time were also recorded for each observation. The perpendicular distance of each deer group to the transect line was calculated using a spatial join in ArcMAP (ESRI, Redlands, California).

To estimate density we used program DISTANCE 6.0 (Thomas et al. 2010). Prior to model fitting, we examined detection frequency histograms for evasive movement, imperfect detection near a distance of zero, and outliers. We also examined quantile-quantile (qq) plots for violations in assumptions concerning inaccurate measurements of distance as well as

assumptions concerning imperfect detection on the transect line. We right-truncated data to improve model fit as recommended by Buckland et al. (1993). We right-truncated data at 450 m based on observation of detection probabilities in Program DISTANCE and knowledge that our laser rangefinder used to estimate distances in the field had limited accuracy further than this distance.

We screened all models using a goodness-of-fit test based on Kolmogorov-Smirnov goodness-of-fit tests and Cramer-von Mises tests (uniform and/or cosine weighting function). These tests were used to test the null hypothesis that the observed data set comes from the same distribution as the expected distribution. Larger p -values indicate a better fitting model, and models with p -values less than 0.05 were not used.

Various models differing in key function and series expansion terms were fitted during modeling. Only the half-normal and hazard-rate key functions were utilized as uniform and negative exponential key functions generally showed a poor fit. Only models that passed initial goodness of fit tests were incorporated as final candidate models. Final model selection was based on examining differences in AIC values of candidate models, with the best model indicated by the lowest AIC value.

Since deer commonly form social groups, conventional distance sampling analysis incorporates a technique that uses clusters of objects (deer groups in this case) to calculate the density. In its simplest form, the average group size (cluster-size) is multiplied by the density of groups to come up with the final individual density estimate. However, observed cluster-size (S) is often influenced by the perpendicular distance of that group to the observer. Therefore, techniques were used to correct for any possible bias by regressing the observed (S) to

perpendicular distance. Size bias regression techniques were implemented if correlation coefficients (r^2) were greater than ± 0.3 with an alpha of 0.15.

For 2011-2012 data, we calculated estimates of deer density (D), group density (DS), and group size (S) for each fall and winter season. To assess temporal variation in deer density, we utilized the individual 15 transects as spatially replicated sampling units. Estimates of variance within a temporal session are thus independent of the geographic variation averaged among the transects surveyed in the season. Because some sessions had a low number of observations (< 50) relative to our ability to model detection probability, we used post-stratification procedures to estimate the detection function globally, but with encounter rate and cluster size utilized from each night. Point estimates for each nightly session, season, and sampling year (a continuous fall and winter season) were calculated for D , DS , and S .

To assess localized spatial heterogeneity in deer density measures, we utilized temporally repeated surveys to derive the average density for each transect. This replaces the individual transects as the sampling unit with the nightly sessions, therefore replicate surveys are distinguished temporally. Point estimates of D , DS , and S were derived for each transect. There were not a sufficient number of observation of deer collected in 2010 to estimate density on a transect, season, or session level. For 2010, all data was pooled to estimate an overall density for the 2010-2011 sampling period.

To determine factors related to estimates of density across various transects, we calculated the area of woodland patches and croplands present within a 450 m buffer around each line transect. We calculated Pearson Correlation coefficients to determine if the point estimate of deer density for 2011-2012 was correlated with either the proportion of croplands or woodlands along an individual transect (SigmaStat).

Results

We found evidence of some seasonal variation in group density, with estimates of group density being higher during the fall season in 2011-2012 (Table 1, Fig. 1). We found that the estimated group size was higher during the winter season in 2011-2012 (Table 1, Fig. 1). Density estimates also varied across transects (range = 0.14 – 38.89 deer / km²), with some transects having high densities of deer and other areas in the refuge having relatively low densities (Fig. 2). The density of groups also varied spatially, and typically higher group densities were associated with higher deer densities (Fig. 3). There was no evidence of correlation between group size and density of deer based on estimates from 2007-2012 (Pearson product moment correlation coefficient = 0.28, $P = 0.65$). Our estimates for group density in 2010-2011 (2.16 groups / km²) and 2011-2012 (4.08 groups / km²) were slightly lower than for the previous years of the study (Fig. 4). Estimates of deer density in 2011-2012 (9.13 deer / km²) were similar to previous years, while density was lower in 2010-2011 than in previous years (4.09 deer / km²).

The proportion of cropland present within a 450 m buffer surrounding an individual transect was positively correlated with both the density of deer (Pearson correlation coefficient = 0.55, $P = 0.03$) and density of groups present on that transect (Pearson correlation coefficient = 0.58, $P = 0.02$). However, the proportion of woodlands present on a given transect was not correlated with either the density of deer on an individual transect (Pearson correlation coefficient = -0.152, $P = 0.58$) or the density of groups (Pearson correlation coefficient = -0.18, $P = 0.52$).

Discussion

Similar to findings by Blecha et al. (2010), we found seasonal variation in group size and group density with smaller group sizes and higher group densities during the fall and a larger group sizes with lower group densities during the winter. This pattern probably indicates a seasonal pattern of aggregation of deer groups that may occur during the winter (

Table 1. Estimates of group density (DS), deer density (D), and group size (S) during 2011-2012. Spatial replicates (transects) were used to estimate densities across nights sampled.

Date	Group density (DS)	Deer density (D)	Group size (S)
11/17/2011	5.03 (2.79, 9.07)	7.98 (4.37, 14.6)	1.56 (1.37, 1.82)
12/19/2011	4.47 (2.31, 8.63)	8.6 (3.4, 21.7)	1.93 (1.0, 3.95)
1/14/2012	2.69 (1.25, 5.78)	9.28 (4.1, 20.9)	3.44 (2.45, 4.86)
2/18/2012	2.18 (1.1, 4.32)	6.14 (2.69, 13.97)	2.81 (1.67, 4.72)
3/25/2012	4.88 (2.8, 8.5)	11.5 (6.5, 20.5)	2.36 (1.94, 2.87)
4/21/2012	5.21 (2.97, 9.12)	11.2 (6.31, 19.91)	2.15 (1.87, 2.5)

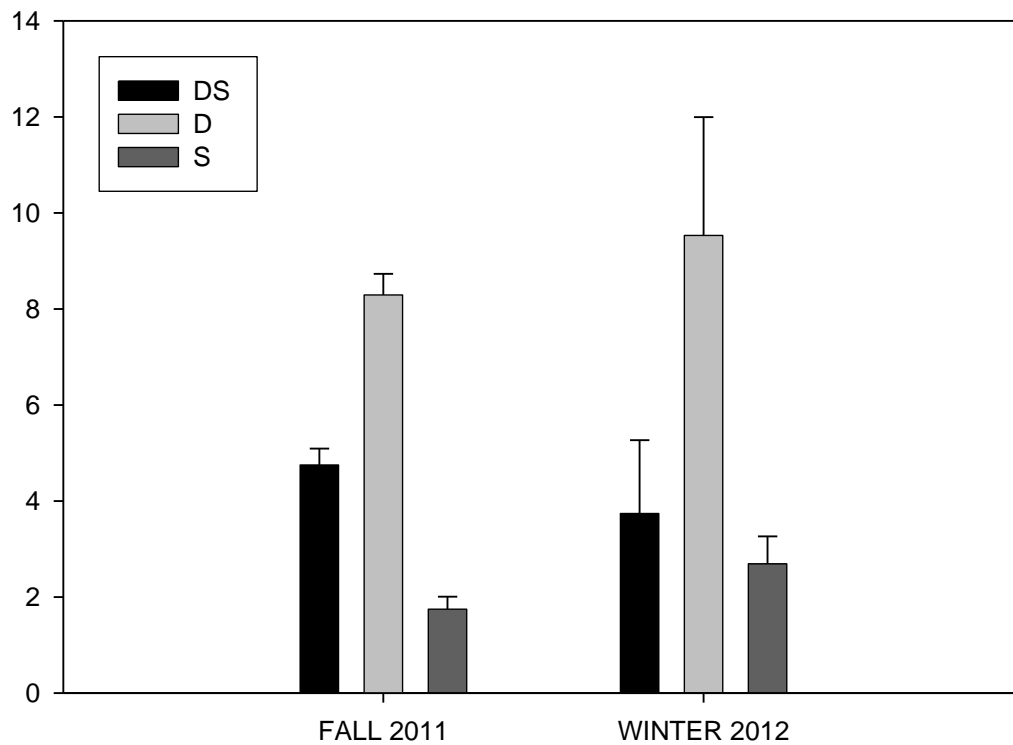


Figure 1. Seasonal estimates of density of deer groups / km² (DS), density of deer / km² (D), and group size (S) for fall 2011 and winter 2012 at Quivira National Wildlife Refuge. Error bars represent 1 standard deviation from the mean.

Table 2. Estimates of group density (DS) and deer density (D) for white-tailed deer at Quivira National Wildlife Refuge during 2011-2012 for each transect.

TRANSECT NUMBER	Group Density (DS)	Deer density (D)
1	0.82	1.32
3	0.143	0.143
4	2.99	5.74
5	1.92	1.17
7	5.1	10.89
8	5.37	11.74
9	13.73	38.89
10	3.32	6.27
12	2.23	4.6
14	2.79	7.85
16	8.28	21.61
17	7.36	14.38
18	2.41	4.83
21	1.8	2.71
22	2.7	5.02

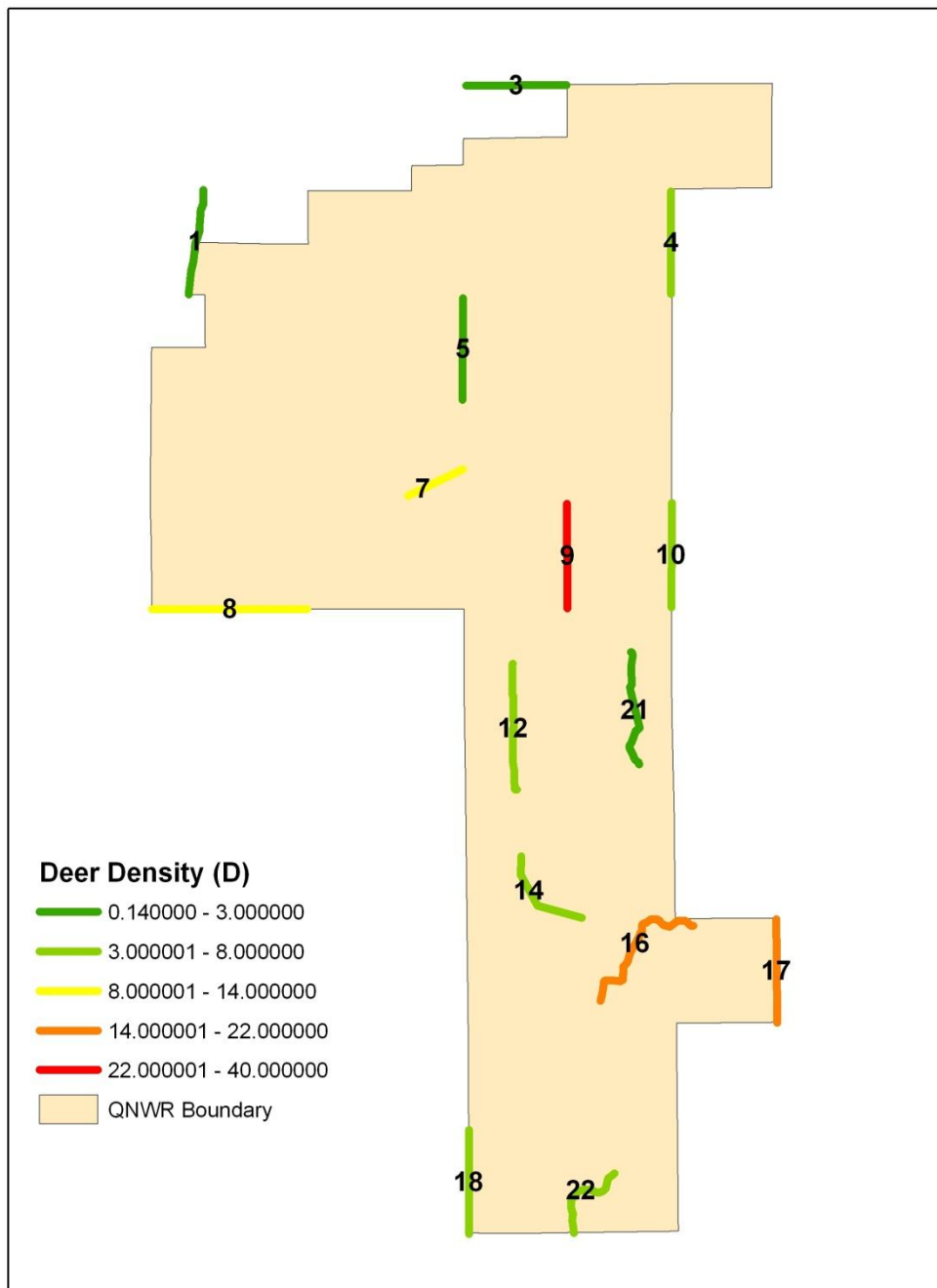


Figure 2. Average density (deer / km²) of white-tailed deer at Quivira National Wildlife Refuge during 2011-2012 for each transect.

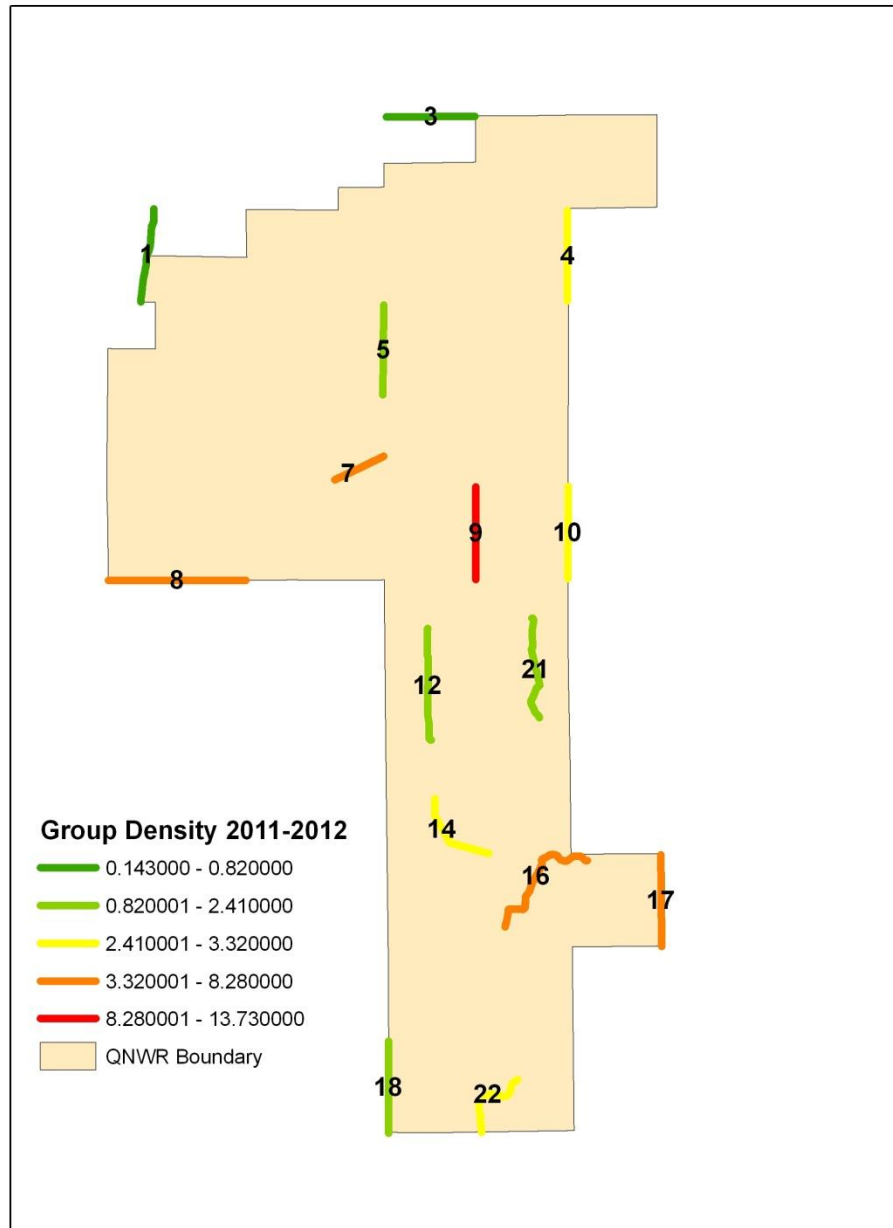


Figure 3. Average group density (deer groups / km²) of white-tailed deer at Quivira National Wildlife Refuge during 2011-2012 for each transect.

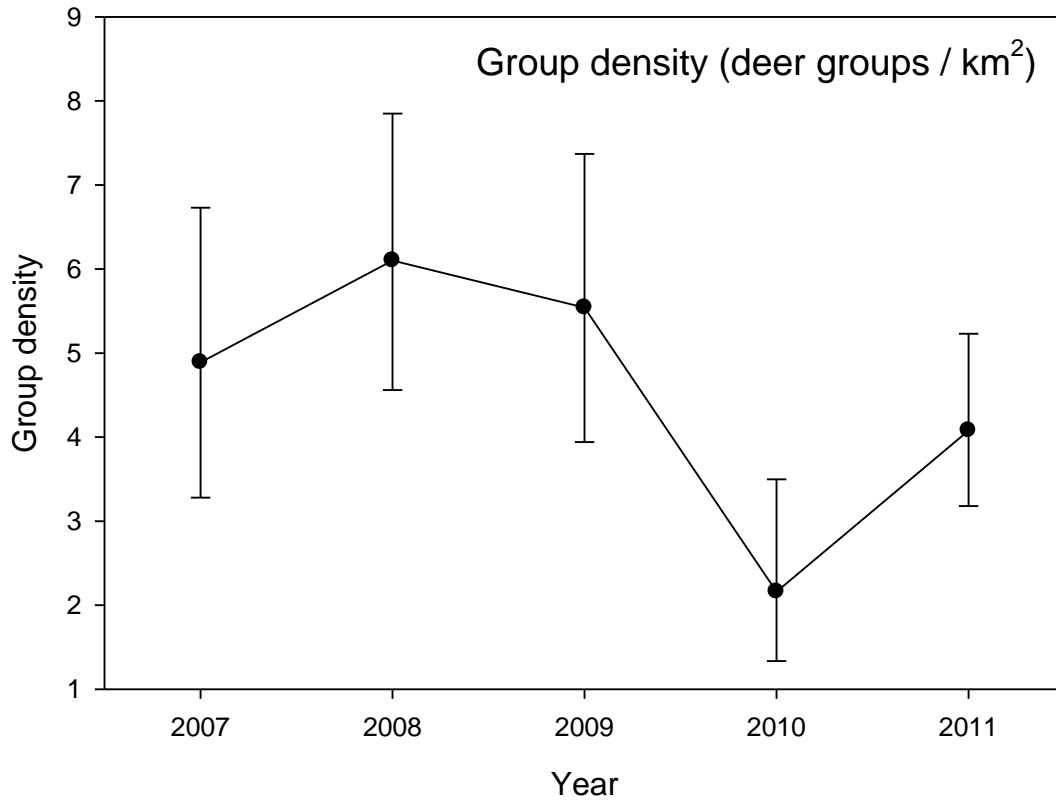


Figure 4. Annual estimates of group density (DS) from 2007 – 2012 at Quivira National Wildlife Refuge. Densities from 2007-2009 are based on fall surveys and data from 2010-2011 are based on both fall and winter surveys.

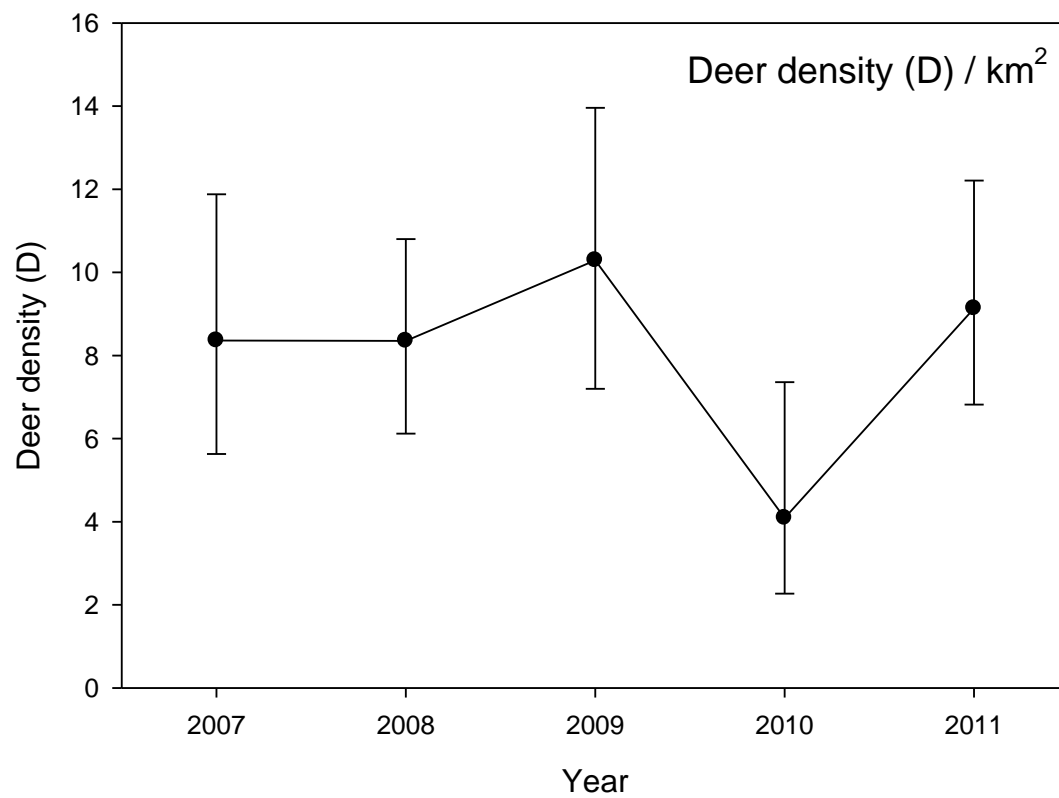


Figure 5. Annual point estimates of deer density (D) from 2007 – 2012 at Quivira National Wildlife Refuge. Densities from 2007-2009 are based on fall surveys and data from 2010-2011 are based on both fall and winter surveys.

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